AD 270 942

Final Report

REQUIREMENTS, CRITERIA, AND MEASURES OF PERFORMANCE OF INFORMATION STORAGE AND RETRIEVAL SYSTEMS

Prepared for:

OFFICE OF SCIENCE INFORMATION SERVICE
NATIONAL SCIENCE FOUNDATION
WASHINGTON, D.C.

By: C. P. Bourne G. D. Peterson B. Lefkowitz D. Ford

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December 1961

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SRI Project No. 3741

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ABSTRACT

A preliminary study was made of the requirements, criteria, and measures of performance of information storage and retrieval systems. ~~Using an interview guide and a methodology developed during this study,~~ a total of 92 applied electronics researchers and 11 metallurgists were interviewed ~~in an attempt~~ to measure and rank several different requirements for information. It was found that some requirements could definitely be measured, and that there was general disagreement among the users about the relative importance of various information requirements. The methodology and the interview guide could be extended, with minor modifications, to other technical subject fields. In addition, ~~to the study of information requirements,~~ three separate and complementary tools were developed for the analysis and evaluation of information retrieval systems: (1) a coarse screening procedure; (2) two different performance evaluation procedures; and (3) two cost analysis procedures that used computer programs to simulate the operation of candidate systems to determine their operating costs over wide ranges in operating conditions. A general functional model of a storage and retrieval system was developed for use by these cost analysis programs. A number of specific research tasks are also suggested to further develop the techniques for the determination of user requirements and the measurement of the performance of information storage and retrieval systems.

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ACKNOWLEDGMENTS

Many individuals have contributed directly or indirectly to the success of this project. We are particularly grateful to three California industrial organizations that generously permitted their employees to be interviewed, and provided the necessary arrangements and facilities--IBM Laboratories, San Jose; Lockheed Missiles and Space Co., Palo Alto; Sylvania, Mountain View. In particular, thanks are extended to the following individuals of these organizations who made our visits so successful: Messrs. R. O. Gruver and R. E. Lawhead at IBM; Messrs. E. S. Burke, W. F. Main, and J. P. Nash at Lockheed; and Messrs. L. W. Cutler, R. Hutter, H. E. King, M. E. Lowe, and R. Morse at Sylvania.

REQUIREMENTS, CRITERIA, AND MEASURES OF PERFORMANCE OF INFORMATION STORAGE AND RETRIEVAL SYSTEMS

I INTRODUCTION

Increasing amounts of money are being spent by government and commercial organizations for complex systems and equipment for the partial mechanization of the operations of collection, storage, and retrieval of scientific information. In addition to this equipment cost, a large amount of money is being spent to support special information services and centers. Undoubtedly, the main objective of these efforts is to increase the productivity of those people who must use scientific and technical knowledge to further their work. The present and projected rates of generation of scientific knowledge, and the greater reliance of all societies on progress through science, give growing importance to the making of correct choices among proposed information storage and retrieval systems.

There are no simple rules by which intelligent choices can be made among the many information systems that are pressing for attention. Many of these systems involve not only large complexes of files and information specialists, but also extremely expensive equipment. In the face of a whole array of such intricate information systems, the evaluative techniques known to systems engineering and to operations research are hard pressed to select from the competing alternatives those that will most efficiently satisfy the users of scientific information within specified time and cost constraints. The problem is aggravated by the consideration that the stakes involved in the choices are likely to increase with time. This is because the information retrieval systems proposed in the future to assist the scientist will be apt to cost more than present ones; however, in return they will undoubtedly offer greater gains.

There is an immediate need to make choices among the present array of systems and machines for information retrieval. The lack of sophisticated techniques by which such comparisons can be made calls for the

rapid development of rough but logical measures-of-worth for candidate systems. At the same time, a need exists for the development of a longer-range research effort aimed at improving the methodology for comparison of information systems. Such research would ultimately result also in a better understanding of the role of information systems in increasing scientific productivity.

The work reported here was directed primarily to the first need--namely, the fairly rapid development of rough measures-of-worth for candidate systems. Specifically, the objectives were fivefold:

(1) To develop a methodology for determining users' requirements

(2) To obtain specific data about the information requirements of a particular community of users

(3) To develop a preliminary set of criteria and a procedure that can be applied to existing information retrieval systems in order to reach tentative conclusions about the desirability of such systems

(4) To develop specific measures of system performance

(5) To develop plans for a research program for the longer-range development of more basic and exhaustive criteria and methods for the assessment of alternative systems and procedures.

Many useful user studies have been conducted in the past, but few of them have been directly concerned with methods for measuring requirements. For example, several studies determined the type of journals that were read, the places at which reading was done, and the complaints that users had about present library service. The present study has been successful, to a limited degree, in developing an interim methodology by which some of the requirements of the users can be measured and described in quantitative terms, for nearly any technical field that requires continued reference to technical literature.

Engineers and other scientific and technical workers have requirements for many different types of information such as: (1) current awareness; (2) specific information to help with current project work; (3) exhaustive searches that are usually performed as a separate project, or as a prelude to the major effort of a project. This study restricted its attention to the second and third types, while considering the requirements for formal technical literature (e.g., books, journal articles, report literature, and conference proceedings) and the types of information request that would likely be directed to a national library or special information center for a particular subject field. The evaluation procedures were developed to assess the degree to which storage and retrieval systems satisfied these types of requirements. These procedures are preliminary, and need improvement.

In addition to the improvement of evaluation procedures, a great deal of work still remains to be done to find ways in which the users' needs for information can be determined accurately. The users' requirements must be described in greater detail before any evaluation procedures are implemented. If they are not, then the evaluation procedures have little significance.

A discussion of the methods for measuring the user requirements, and the results obtained from a sample survey of a specific population of users is given in Secs. III and IV on survey methodology and survey results. Section V describes a generalized functional model of a storage and retrieval system. Section VI describes the criteria, measures of performance, and analysis techniques that were developed, and evaluates three representative retrieval systems using some of these techniques. Finally, Sec. VII provides some suggestions for future research work to extend and improve the results that have been achieved to date. A sample of the interview guide used in the survey, two computer programs, and additional supporting data are included in the Appendices.

II SUMMARY AND CONCLUSIONS

After interviewing over 90 researchers in electronics and 11 metallurgists, it was found that, to a limited degree, information requirements could be measured quantitatively, and measures could be formulated of the relative importance of each of these requirements. The interviews did provide a composite or over-all agreement on the relative importance of seven different factors; the most important of which was agreed to be the response time, the time involved between the request and the receipt of the major group of relevant references. However, there was no strong agreement as to the relative importance of the other six factors. In addition to the difficulty of obtaining true rankings, it is also extremely difficult to measure some of the requirements accurately and quantitatively. Some useful results were obtained with the direct interview approach used here, although with this and many other alternative approaches, it is very difficult to avoid a conditioned response. The statements by a user reflect the type of information service that he is accustomed to getting, so that the study can never really separate need from habit. The critical-incidents approach used here did not provide as clear-cut results as had been anticipated.

Three separate and complementary analysis procedures were developed which give indications of being useful tools for the evaluation of storage and retrieval systems. The first tool, a coarse screening procedure, arranges empirical data to show the ranges of parameter values that are likely to be encountered by candidate systems. This tool could be used immediately; it can also be refined to make it even more useful. The second tool, a performance evaluation procedure, relates system performance to user requirements--while considering the relative importance of each of these requirements--to arrive at a single figure of merit or performance figure for each candidate system applied to each user population of interest. The second tool can be implemented in two different ways: (1) direct quantitative measurement and correlation of the performance and requirements, with quantitative weighting

for the relative importance of each requirement, or (2) the reduction of all the requirements and performance to a common denominator of time or cost. The first way has some limitations but could be implemented in the near future if the quantitative data describing the requirements and performance were available. The second way seems to be a more accurate approach but needs further development before it can be used. The third tool, two cost analysis procedures and programs used a computer and some modelling programs to simulate the operation of specific storage and retrieval systems using basic data on time, cost, and equipment capabilities, to arrive at estimates of the total operating costs of a candidate system over wide ranges in operating parameters such as file size, accession rate, and volume of search requests. The cost analysis procedures utilized a general functional model of a storage and retrieval system developed during this study. Both cost analysis procedures were successfully applied to three representative systems; the results suggest that, given the basic descriptive information, the two programs could be usefully employed right away for the analysis of specific candidate systems. The computer programs were written in ALGOL, a universal programming language, so that they can be used by any other interested group.

The work to date on this six-month study represents a very preliminary effort to obtain solutions to an extremely difficult problem. Continued studies are necessary to achieve more accurate and useful evaluation procedures and measures of performance. It is felt that the following problem areas would be good targets for immediate and long-range research:

(1) Development of methodology for determining user requirements

(2) Determination of elemental times and costs of the basic operations performed in storage and retrieval systems

(3) Development and use of modelling for performance evaluation

(4) Development and use of modelling for analysis of operating costs

(5) Pilot tests or pilot evaluations of representative systems

(6) Additional basic studies.

III A METHODOLOGY FOR MEASURING USERS' INFORMATION REQUIREMENTS

A. General Methods

A number of different approaches can be taken to determine the information requirements of the user of a retrieval system. Generally, the approaches might be characterized as follows: (1) study of the user's information environment; (2) study of the present information resources (a special part of the information environment); (3) study of the user. Methods appropriate to each of these approaches are discussed below.

1. Study of the User's Information Environment

This approach examines some of the economic and time pressures or practical constraints present in the user's environment that limit the information resources the individual can utilize.* These constraints are not likely to change very significantly no matter how many new and improved information retrieval systems are provided; consequently, an understanding of the constraints is of great importance. These constraints might be explored with questions such as these:

(1) How much do organizations spend now for information services--and how much do they feel they can afford?

(2) What total volume of literature is currently made available to the user in his own organization? This reflects the organization's scope of interest, and its budget for information services.

(3) What total volume of literature is of frequent personal interest to the worker? This represents the parameters of the file which satisfies a good fraction of the information needs of the individual worker.

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*For example, regardless of the type of information or services available, an individual or organization still has a limited amount of time or money to spend for information.

(4) What is the amount of time that a worker can afford (because of cost or other pressures) to spend in reviewing or searching the literature?

2. Study of the Present Information Resources

The quality of service of the user's present information resources provides a lower bound for the requirements of any proposed alternative system. That is, any new retrieval system should provide at least as much service and value as the system it is to replace. Since the present habits and actions of the user reflect, to an unknown degree, his needs and requirements, we might consider the following questions:

(1) How are libraries and information services actually used (functions, type of material, type of user, type of questions)?

(2) What are the operating statistics of present systems (volume of questions, number of users, budgets, staffing, file size, input rate)?

3. Study of the User

Unfortunately, information about the user is extremely difficult to obtain. Measurements are difficult, if not impossible, and most studies resort to judgements or opinions. The user himself is frequently a poor source for direct comment on his needs; he is usually influenced by the tools and facilities that he is familiar with, and he usually cannot discriminate between his actual needs and his way of performing work. Any of the following methods, or combinations of them, might be used to obtain information about the user's requirements:

(1) Ask the users specific questions about what they think their requirements are (e.g., tolerable delay, form of resulting product, types of service preferred).

(2) Ana'vze recent information requests. Probe t circumstances that motivated the request for information. Determine the parameters--such as response and error rates--that would have been tolerable in a particular situation. Find out the nature of any disappointments or unsatisfactory results. Taking advantage of the user's hindsight, find out what he would like to have obtained in the way of specific products or services.

(3) Monitor the establishment and fulfillment of a research project or experiment, and note the specific needs and requirements as they occur. Although realistic data may be obtained in this way, the method has the disadvantages of interferring with the working group, requiring a relatively long lag time for completion of the data gathering through a complete project schedule, and probably requiring a relatively large amount of observer's time for a number of different projects in order to obtain statistically significant data.

(4) Postulate a "perfect" retrieval system; then allow people to pose questions to the system.

(5) Determine the functions (e.g., preparation to learn new techniques, to learn experimental results, to plan new research, to prepare lectures, to keep abreast, etc.) of the various portions of the information services and find out how well each of these functions is being met. The dual of this method is to examine the various portions or channels of the information system (e.g., abstracts, books, journals, advertisements, etc.) and find out the functions that each of these channels serve.

(6) Measure the result that a user usually obtains (by performing his regular type of search) and compare it to the result that can be achieved by an exhaustive search of all available resources. This would give some indication of the amount of overlooked material he could tolerate.

(7) Perform a controlled experiment in which identical or comparable tasks are performed by groups with different information resources. This would give some indication of the relationship between user productivity and the availability of information.

(8) Record, in some uniform measure, the amount of information that is normally available to the individual in his own office. This would give an estimate of the scope of interest or range of coverage of the individual user, and would show how large a file of information he considers sufficiently important to warrant the expenditure of his own time and money.

(9) Determine the circumstances surrounding the critical requirements for information. (That is, those requests for information that are critical or fundamental to the solution of a given technical problem.)

This project asked the user specific questions [see (1) and (9)] with the aid of the survey techniques described below.

B. Description of the Survey Technique

A survey technique, using personal interviews among a specific user population, was selected for determining user requirements in this study. A preliminary interview guide, incorporating the so-called critical-incident approach as well as direct questions, was developed after some

intensive interviews and after discussions among members of the project team. The preliminary guide was pre-tested among nine electrical engineers on the Institute staff.

The final interview guide* was designed to obtain four kinds of information:

(1) A list of critical requirements, using the critical incident technique[1]**

(2) Measurements of selected requirements that were considered both important and susceptible to measurement (Some requirements known to be important were unavoidably omitted because of the preliminary nature of this project.)

(3) Rank order of the importance of seven factors that were believed to be important to users and were amenable to ranking

(4) Background variables that might influence the user needs (company, age, academic degree, specialty field, type of search, and the like).

The focus of the interview was on the most recent search conducted by the individual. Two of the 94 individuals contacted had not conducted a search in the past year and were not interviewed.

The approach of limiting the interview to the most recent search (and consequently reflecting the performance of the present system available to the individual) was considered at length by the project

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*The interview guide was simply a guide and recording form for the interviewer. It was <u>not</u> a questionnaire, and it was not meant to be read or closely examined by the test subjects.

**The critical incident technique is a method for identifying requirements that are of particular importance to the success of a task--in this instance, a literature search. This is described more fully in Section III. For a more detailed description of the critical incident technique, see Ref. 1. (All references are listed at the end of the report.)

team. There were three major arguments for this approach:

(1) That respondents could talk realistically about the present system

(2) That their needs remain constant regardless of the system available

(3) That any contemplated new system would have to be equal or superior to the present system.

There were two major arguments against the approach:

(1) That a new system might offer such vast improvements that answers concerning the present system would not be meaningful

(2) That the users' statements of needs are definitely conditioned by the service they are presently accustomed to.

The possibility of asking respondents to answer in terms of an "ideal" system was considered. This was rejected because it was believed that answers might be given that are unrealistic in terms of present capabilities (e.g., "I want 100% of the world's relevant material and no irrelevant material within one hour of my request.").

Giving the respondents a choice of various system capabilities was also considered. For example, respondents could have been asked to choose between many pairs of systems, such as the following:

(1) A system that in 24 hours produced documents of which 50 percent were irrelevant, versus a system that in one week provided only the relevant documents;

(2) A system that produced all the relevant documents but many irrelevant documents, versus a system that produced few irrelevant documents but might miss a few relevant documents.

This technique was rejected because the number of variables, and consequently the number of alternatives that would have to be presented

to the respondent, was too great. It was difficult to imagine that many respondents would be willing to take the time and effort to make all the choices from the pairs of alternatives.

The interview in its final form took about 45 minutes per individual. General interest in the subject was high, and the cooperation of respondents was excellent.

C. Description of the Sample Population

Test subjects were chosen from persons doing applied research in the field of electronics. Eleven metallurgists were added later. For the main purposes of the project, the choice of population was not critical; this is because our prime interest lies in developing the methods of measurement, and in determining which requirements can be described analytically, and which requirements must receive a judgmental description. In order that results can be validly compared with the results of other surveys, it is important to describe the population accurately; details of the measurement of this particular population may be useful for other purposes also.

The exploratory nature and scope of the study did not permit a precise sample of a known population. Stanford Research Institute and three California industrial firms* each provided approximately equal numbers of test subjects.

A sample of persons engaged in many fields of applied electronics research was selected in each firm, with a total of 92 persons receiving personal interviews that generally lasted about 45 minutes. The great majority of subjects held academic degrees in electrical engineering. A few held a degree in another field (primarily physics). An attempt was made to obtain a greater number of workers with higher academic degrees and in higher job levels than would be obtained with a random

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*IBM Laboratories, San Jose; Lockheed Missiles and Space Co., Palo Alto; Sylvania Laboratories, Mountain View.

sample, so that the results could be examined according to these variables. Detailed tables of the characteristics of the sample population may be found in Appendix F.

In addition to interviews with electronics researchers, interviews were conducted with 11 metallurgists. One was interviewed at Sylvania, and a sample of ten were interviewed at Lockheed.

The analysis and summary of the interview responses of the electrical engineers, are given in Sec. IV.

D. Initial List of Requirements

In order to define and describe the information requirements that were to be selected for measurement, the project team initially developed a list of many parameters that were felt to be important. A large amount of published material was reviewed to uncover additional parameters, and discussions were held with a number of informed individuals outside SRI. The resulting list of requirements was rather large, and was subsequently reduced to a more manageable group of about 40 requirements which seemed to fall naturally into five different categories. These are described below.

1. General Requirements for All Alternative Systems

General requirements are those that are common to all candidate systems and can be satisfied in the same way and with the same costs and results for each alternative system. Consequently, they do not contribute to a comparison of the differences between the candidates, and should be separated from the rest of the requirements. For example, there is a requirement that each file be as complete as possible in the subject fields of interest to the users--for the user that is choosing between alternative ways to implement his file, this is an acquisition problem common to all the alternatives under consideration. These general requirements must be considered in the over-all evaluation of a system, but are not considered in the detailed analysis and comparison of specific systems. The following are examples of such general requirements:

(1) Acquisition of high-value, timely, technically excellent file material

(2) Provision for translations of foreign language material

(3) Provision for throw-away copies of requested file items.

2. Search Product Requirements

The following requirements are concerned with the actual search product given to the requestor:

(1) Specified format of search product (document number, reference or citation, abstract, reprint)

(2) Specified physical form of search product (microfilm, paper, etc.)

(3) Specified quality of printing

(4) Reliable indexing and search products (i.e., assurance that you always get what you ask for).

3. File Material Requirements

The following requirements are concerned with the material in the file:

(1) Need for a certain type of information to be included in the file (technical papers, books, patents, reviews, etc.)

(2) Capability for accepting information written in the important foreign languages

(3) Capability for storing graphic material (equations, diagrams, chemical structures, etc.)

(4) Capability for storing a certain volume or quantity of information

(5) Compatibility with other information and communication systems

(6) Protection against loss of stored information (e.g., protection of information on magnetic tape).

4. User Requirements*

The following considerations relate to the actual "over-the-counter" services given to the user by the information services staff and are of direct interest to the user of the information services:

(1) Amount of relevant material overlooked during the search

(2) Amount of irrelevant material provided

(3) Delay in getting the first, final and major group of relevant references

(4) Ease of communication between the system and user (codes, languages, media)

(5) Complexity of search logic that can be accommodated

(6) Completeness of coverage (core and fringe material, recent and past literature)

(7) Provision for alternative mode of operation (e.g., manual) if one or more of the system parts become inoperative

(8) Indications of the technical competence of each search product

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*A distinction is made in this section between the "users" who come to the system seeking service, and the "operators" who operate and maintain the system. The "operators" in many cases are the only ones that actually use the system--in the sense that they operate the equipment and search the files.

(9) Immediate and continuous availability for searching or file browsing directly by the user, with a minimum of effort on his part

(10) Ability to control and handle language problems with minimum inconvenience to user (synonyms, jargon).

5. System Management Requirements

The following requirements are concerned primarily with the behind-the-scenes operation of the information service, and are of most interest to the organization that is providing and operating the service:

(1) Provision for easy re-indexing, purging, file maintenance; and the capability to provide a duplicate of the classification and indexing information

(2) Minimum need for space, power, and special installation or operating facilities

(3) Minimum need for training, retraining, or specialization of system personnel

(4) Growth capability (file size, subject diversity, volume of searches, etc.)

(5) Self-analysis to recover misfiled information, note missing information, obtain operating statistics on system use and performance, generate indexes or catalogs, and provide information for management and system control

(6) Costs (equipment purchase or rental, maintenance, spare parts, parallel testing, conversion, initial development and programming, indexing, reproduction, storage, training, staff, etc.)

(7) Ability to coordinate the system with similar services in the same or alien subject fields

(8) Ability to conduct a specified number of searches within a given time period.

The type of user interviewed in this study is generally not qualified to comment on these behind-the-scenes requirements. Library managers would be better qualified; however, none were contacted on this project because our attention was concentrated on the study of the requirements of the ultimate customer of such an information service.

Because of practical restrictions on time, money, and the patience of the test subjects, measurement of every one of these requirements could not be attempted. Consequently, those requirements that were felt to be most important, and had some promise of being measurable, were selected for detailed study. It was felt initially that the following factors were most important:

(1) Type and form of search product (document number, reference or citation, abstract, reprint; on paper, on film, etc.)

(2) Reliability of the indexing and search product (i.e., credibility of the product and the knowledge that one always gets an accurate search product)

(3) File capacity

(4) Delay in entering new information into the system

(5) Automatic removal of obsolete or redundant material

(6) Amount of relevant material overlooked during the search

(7) Amount of irrelevant or redundant material provided with the search result

(8) Immediate and continuous system availability for searching or file browsing directly by the user

(9) Delay in getting the first, final, and major group of relevant references

(10) Total number of searches that can be handled in a given time period

(11) Ease of communication between system and user (codes, languages, media)

(12) Provision for alternative mode of operation (e.g., manual) if one or more of the system parts becomes inoperative.

The following three items are important, but the user is generally not qualified to comment on them:

(1) Cost

(2) Capability for easy re-indexing, purging, correction, and file maintenance

(3) Capability for self-analysis to recover misfiled information, note missing information, obtain system operating and performance figures, and generate indexes or catalogs.

E. Requirements That Can Be Measured

The measurements that were made are crude, and often consist of only a few data points. However, the measurement techniques can be refined to obtain greater accuracy and more resolution. At this point, it seems certain that for a given user population the following group of requirements can be quantitatively measured, and that we can have at least some confidence in the results that are obtained:

(1) Desired, actual, and least tolerable delay in obtaining the first, final, and major group of search products

(2) Desired, actual, and least tolerable currency or minimum age of the file contents

(3) Desired, actual, and least tolerable format of search product (abstract, citation, etc.)

(4) Desired, actual, and least tolerable physical form of search product (paper, microfilm, etc.)

(5) Desired, actual, and least tolerable amount of irrelevant material furnished

(6) Size of the file required to satisfy various search needs

(7) Tolerable expenditures of effort to obtain more current information

(8) Tolerable delay for various fractions of the total amount of relevant information.

It also seems certain that the relative rankings of a given set of requirements can be determined without too much difficulty. Methods for determining the rankings and ascertaining their confidence levels are described in a subsequent section.

There were some relatively important requirements for which measurements were not made:

(1) Tolerable fraction of relevant material that can be overlooked

(2) Tolerable amount of effort required by the user to communicate with the system.

For a number of reasons, both of these requirements are extremely difficult to measure, and no method was found that could be applied on this short study. Several aspects of the question of overlooked relevant

material have been studied recently by a number of people, but their efforts have been concentrated primarily on instrumentation or methodology, and they have not obtained specific measurements.[2-6]

In addition to obtaining some specific measurements of the requirements, some background material was also obtained (see Sec. IV and Appendix F) to describe the circumstances surrounding the requirements, such as: What types of work activities generate the search requests? Who actually conducts the searches? What search facilities were used?

F. Suggestions for Improvement of Survey Methodology

In view of the exploratory nature of this study, it is obvious that some improvements in the interview guide can be suggested. The following suggestions refer only to changes in the interview guide (see Appendix F); suggestions for additional research are covered in Sec. VII.

(1) There was some confusion about the term "search," in spite of the definition given respondents. A search may consist of two separate operations: looking for references, and obtaining the documents. Consideration might be given to conducting the interviews separately for each of these two processes, particularly where existing manual systems tend to divide the two into separate tasks.

(2) The critical-incident technique could perhaps be refined to elicit better responses and ones that were more system-oriented. A number of comments referred to requirements that no system could be expected to meet (e.g., "not enough written" "subject too current").

(3) Some of the questions and answer categories could be refined. In particular, if a larger population is studied, the time categories could be increased in number so that a smaller period of time is covered by each category.

(4) The procedure and wording for rank ordering of selected requirements should be reviewed. First, the wording of the instructions could perhaps be shortened and made clearer. If possible, the degree to which the requirements are in conflict should be explained. Second, the wording of the requirements could be improved. Third, some additional requirements could be included.

(5) The items concerning time or effort spent vs. completeness of the search are now of questionable value and can probably be dropped. These items were admittedly experimental. While respondents answered as best they could, it is doubtful that they can realistically provide precise data.

IV SURVEY RESULTS

The results of the survey are discussed in detail in Appendix F. The purpose here is to give an over-all view of the needs of the individuals interviewed for this study. For this purpose, the survey results will be reviewed briefly. All data refer to the sample of electrical engineers, except for a short section at the end dealing with metallurgists.

A. Frequency and Types of Searches

As stated earlier, 92 of the 94 electrical engineers contacted had conducted or requested at least one search in the last year. The number of searches per individual varied widely. Responses were about equally distributed among the following categories: 1 or 2 searches in the past year, 3 to 5, 6 to 10, and 11 or more (see Question 2 of the Interview Guide in Appendix F).

The work activities that generate the most searches are not necessarily those in which the most working time is spent. "Search for novel technical ideas," "preparation of lectures or technical papers," and "keeping current with technical advances" were mentioned by 8 percent, 2 percent, and 1 percent, respectively, as the one activity in which the most working time was spent. These same activities, however, accounted for 20 percent, 12 percent, and 11 percent, respectively, of the most recent searches reported by respondents. An exception was design of equipment, systems, and procedures. Almost half the respondents indicated that this was the one activity in which they spend the most working time, and 30 percent said their most recent search concerned this activity (Questions 3a and 3b, Appendix F).

Greater importance was attributed to the search when it was initiated than to the results of the search. Of the respondents, 78 percent rated the search important when it was started but 54 percent said that the results had made little difference to them when the search was completed. These responses may have occurred because the answer categories to the two relevant questions were not identical (Questions 9 and 10, Appendix F).

B. Critical Requirements

Some exploratory questions were asked using a technique modeled after the critical-incident technique, mentioned in Sec. III-B. The purpose of these questions was twofold. First, they were intended to determine whether or not there were a few "critical" requirements--that is, a few outstandingly important criteria. The second purpose was to provide some indication as to whether the list of requirements selected for measurement in the study excluded some important ones.

Respondents were asked to state the most difficult or irritating thing that occurred during their last search and to name the easiest or most gratifying thing that happened. The results of these two questions are shown in Table I. They were also asked what advice they would give a new young engineer embarking on the same type of search to make the search easier and what pitfalls they would point out to him. Table II contains the tabulation of responses to these questions.

The responses--perhaps due to the wording of the questions--were extremely varied. The interviews showed that instead of there being several requirements that are of extreme importance, there is actually a wide array, all of which are of some importance to the performance of the system. The list of requirements subjected to measurement during this study did not appear to exclude any of great importance.

The most frequently mentioned factors concerning the subject's last search referred to relevant material produced. There were a number of general comments (28 percent) on the ease with which relevant references were found and documents obtained. There were also a number of comments (26 percent) concerning the ease with which the actual document is found after a reference to it is located.*

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*In this Section, "positive" comments mean those comments that are complimentary to the present system. "Negative" comments are those that are uncomplimentary or derogatory to the present system.

Table I

CRITICAL REQUIREMENTS LISTED BY ELECTRICAL ENGINEERS IN RELATION TO THEIR MOST RECENT SEARCH

	Percent of Engineers Making Comment
SEARCHER	
Subject was in own field	8
Had his own source	7
Gained information personally useful	5
Knew someone or met someone who knew sources	4
SYSTEM--Relevant Material Produced	
Finding references and documents, finding them easily (or finding nothing if that is aim)	28
Ease of getting document after reference to it found	26
Good bibliographies, abstracts, indexes produced	17
SYSTEM--Operation	
Adequate indexing, ease of understanding indexing	15
Ease of communication with system	11
Adequate cross referencing	11
SYSTEM--Irrelevant Material Produced	
Need less irrelevant material	12
SYSTEM--Time	
Receive material in short time	9
SYSTEM--File Size	
Need for foreign literature, translations	7
SYSTEM--Relevant Material Missed	
When you know information exists, want to be able to find it; want to be sure you have all the good sources	5
SYSTEM--Provision of Copies of Documents	
To get copies of material easily	4
PROBLEMS OUTSIDE CONTROL OF SYSTEM	
Material classified, difficult to obtain	8
Subject too new, no material available	5
Not much written on subject	3
Material unpublished, available only from individuals	3
Base	(92)

Note: The above data were obtained by combining responses to the two following questions: Question 5a--"Do you recall anything happening during the search that made it an easier or better search, or that made the search difficult? For example, what was the most difficult or irritating thing that happened?" Question 5b--"What was the easiest or most gratifying thing that happened?" "Other" and "no answer" responses have not been included. Duplicate responses (one individual giving same answer to both questions) were eliminated.

Table II

SUGGESTIONS THAT ELECTRICAL ENGINEERS WOULD MAKE TO A YOUNG ENGINEER STARTING A SEARCH

	Percent of Engineers Making Comment
SEARCHER	
Talk to men who are in the field	23
Be informed on your subject	10
Define the problem clearly, specify scope before starting	17
Go to library yourself, be aware of library facilities	13
SYSTEM--File Size	
Use abstracts, indexes	18
Try ASTIA	12
Use journals in the field	8
Note references and bibliographies given in technical articles	5
Look at bibliographies that are available	4
Try textbooks	4
SYSTEM--Irrelevant Material	
Scan rapidly, discard irrelevant material quickly	11
SYSTEM--Descriptors	
Use enough key words	8
Use computer, descriptors for computer	3
SYSTEM--Time	
Be patient	7
SYSTEM--Evaluation of Material	
Don't believe everything you read, select reliable sources	7
SYSTEM--Relevant Material Missed	
Make sure you look at all sources of information	4
SYSTEM--Time Period Covered by Documents	
Obtain current information--weed out the old	2
OPERATOR OF SYSTEM	
Ask the librarian	16
Don't ask the librarian	3
Base	(92)

Note: The above data were obtained by combining responses to the two following questions: Question 5c--"If a young engineer who had just joined the staff were starting this same search today, what advice would you give him to make the search easier?" Question 5d--"What would you warn him about?" "Other" and "no answer" responses have not been included. Duplicate responses (one individual giving same answer to both questions) were eliminated.

References to good bibliographies, abstracts, or indexes produced by the search were made by 17 percent, almost all in positive terms. Also mentioned by a number of respondents were the indexing system (15 percent) and cross referencing (11 percent). All of these responses were negative.

Of the 11 percent that referred to ease of communication with the system, some found it satisfactory and others did not. Of the 12 percent of the respondents who mentioned irrelevant material, all mentioned it unfavorably.

There were also some responses concerning the last search that are not directly related to a system. For example, there were a number of references to the knowledge and sources the individual brings to the search before starting:

> "The search was a little bit out of my field, which made it harder."

> "I've subscribed to IRE since 1949 so had my own source."

> "I was fortunate enough to meet a man at a Berkeley meeting who knew just where to look."

This type of response was even more frequent in offering advice to a young engineer starting a search. The following comments are typical:

> "Have as much information as you can on the subject before you start."

> "Talk to people who are familiar with this area of investigation."

While no system could perform the functions implied by such comments, it is possible that a system more adequately meeting other direct requirements (e.g., producing all relevant documents on the subject) would reduce the amount of time and effort required of the individual searcher in preparing for the search.

C. Measurement of Selected Requirements

The purpose of the series of detailed questions on the most recent search was to obtain data on requirements that could be measured, and to obtain opinions on those that could not. In the case of file size, minimal information was obtained because of the concentrated effort other studies have made on this one requirement. Four measurements were obtained where possible: actual performance of the present system, desired performance, minimum performance that is acceptable, and rank order of importance in system performance.

Concerning time required to obtain the major group of relevant references, the actual and the needed performance were quite similar. The importance of promptness in providing documents is quite evident. Over one-fourth of the subjects received the references in one day or less, and almost half in three days or less. The minimum acceptable performance level was considerably lower--65 percent could have waited two weeks or more (Questions 11a, 11b, and 11c in Appendix F).

The need for current material was also expressed. About one-third received some documents that were under 3 months old, and a slightly higher proportion (37 percent) said they needed such current material. Minimum performance would have permitted older material. Over half said they would have been satisfied with documents that were all over 2 years old (Questions 12a, 12b, and 12c in Appendix F).

The actual form in which documents came to the users, and their preferences for form, did not coincide closely. The great majority (81 percent) received at least some complete documents. Citations were received by 45 percent, abstracts by 42 percent, and document numbers by only 2 percent. However, 68 percent said abstracts are a preferred form and 64 percent said complete documents are a preferred form (more than one preference could be given). Almost all (97 percent) said that document numbers are an inadequate search product; over half (54 percent) said citations are an inadequate search product (Questions 13a, 13b, 13c, and 13d in Appendix F).

Apparently irrelevant material is not considered to be a great problem among respondents. Concerning the amount of time respondents personally spent on the search, 41 percent said that less than one-fourth of their total time was spent culling out duplicate and irrelevant material. Forty-four percent indicated that less than one-fourth of their effort should be spent in this way. If necessary, respondents would have been willing to spend much more time eliminating irrelevant documents; 45 percent said they would have spent a maximum of three-fourths or more of their time getting rid of unnecessary material (Questions 14a, 14b, and 14c in Appendix F).

General questions were asked to determine who conducted the search, where it was conducted, and how the search request was specified. The great majority of respondents (80 percent) participated personally in the search. Librarians participated in 27 percent of the searches (Question 6 in Appendix F). Almost all respondents said the search was conducted at least partially in their own organization's library. However, other sources were also used, either directly or through the organizational library. University libraries were mentioned by 32 percent, ASTIA by 25 percent, and other sources by 17 percent (Question 8 in Appendix F). There was some variation in the way the search was specified. While almost half (46 percent) said they used specific terms or key words, 23 percent said they described the problem generally, 13 percent said they used several broad headings, and 15 percent said they were "fairly" specific (Table F-1, Appendix F).

Some questions also were asked concerning time and effort vs. completeness of the search. As indicated in Sec. VII, these questions were experimental. The data should be regarded as indicative only, since respondents probably cannot reply realistically to such questions. Respondents were asked how long they could wait for a search covering 50 percent of the potential sources, for one covering 80 percent, and for one covering all or almost all potential sources. Although the trend was definitely toward a longer wait for a greater number of sources, there was little agreement among respondents on the amount of time they

would be willing to wait. Answers were quite varied. The median fell in the 8- to 13-day category for a search covering 50 percent of the sources, in the 2- to 3-week category for 80 percent of the sources, and in the 4- to 7-week category for all or almost all of the sources (Table F-3 in Appendix F).

In the same series of questions, respondents were asked how much of their own working time they would be willing to spend if they could be sure 50 percent, 80 percent, or almost all relevant sources were located. The median fell in the 2- to 4-day category for searches locating 50 to 80 percent of the relevant sources, and in the 1-week but less than 2-week period for a search locating almost all the relevant sources (Table F-4 in Appendix F).

Respondents were also told to assume that a search had covered material up through two years ago, which required X amount of their own working time. They were then asked how much additional time they would personally spend to update the material to within 1 year, within 6 months, and within 1 month. The median category to update from 2 years to 1 year was an additional 1/2 X to 1 X. The median to update from 2 years to 6 months and from 2 years to 1 month was 2 X to 4 X (Table F-5 in Appendix F).

Two broad questions were asked concerning file size. First there was a question concerning how often respondents could have used searches (regardless of existing facilities) covering varying numbers of sources over the last five years of publication. Respondents were then asked how their answers would change if they had not been limited to five years. The great majority (82 percent) often could have used a search covering 15 or fewer journals over the last five years of publication. More extensive coverage, in terms of numbers of sources, could have been used by the majority occasionally. However, even though they were offered the capability, the users seldom wanted to search the entire world's literature to answer their question. Very few respondents said they would have more occasion to search the files listed if they were not limited to the last five years (Questions 19a and 19b in Appendix F).

Although the sample was too small to permit extensive cross tabulations, some of the data were tabulated according to organizational affiliation. The number from each organization is quite small, but some of the differences are worth noting. For example, one participating company has facilities for computer searching. In that company, fewer respondents personally conducted their own search than those in other organizations. The length of time these respondents had to wait to receive references--and the length of time they said they should have to wait--was less than that reported by other respondents. The majority of these respondents received some references in the form of citations, and considered complete documents adequate but preferred abstracts. Respondents from the same company spent a greater proportion of the total time spent on the search culling out irrelevant material and indicated that a larger proportion of time was the tolerable level for this activity than did respondents from other companies. These and other differences, while not conclusive, are evidence that the facilities available to the individual have an effect on his searching habits. It appears that the individual states his needs in terms that are realistic within the capabilities of the system that is available to him.

As stated earlier, 11 metallurgists were also interviewed. The purpose of these interviews was to determine whether or not the interview guide could be applied to persons in other fields. Certain minor and obvious changes would have to be made for subsequent surveys in fields outside of electronics, such as reference to searches in the field of electronics. Interviews with the metallurgists produced minor variations in responses, but in general the guide worked as well as it had with electrical engineers. One difference in response, as would be expected, was the number of references to special information facilities already available within the field of metallurgy.

D. Analysis of Respondent Rankings

In Question 15 of the questionnaire the respondent is asked to rank (arrange) seven document retrieval system characteristics by order of importance--assigning 1 to most important, 2 to the second most

important, and on down to 7, the number assigned to the least important characteristic. If two or more characteristics are considered to be equally important, for instance, if the respondent ties the third and fourth ranked characteristics, then each is alloted the average of the ranks, in this case the rank 3-1/2.

The characteristics, labeled A-G, are:

(A) Minimum time to get the major group of relevant references to you.

(B) Minimum of irrelevant material produced by the search

(C) Minimum of relevant material overlooked by the search

(D) References come to you in form you prefer (complete document, abstract, citation, or document number)

(E) Assurance that documents on a given subject do not exist

(F) Minimum of effort on your part to communicate your request for a search

(G) Certainty that specified sources over certain period of time were searched (certainty that 100 percent of the sources were searched, certainty that 90 percent were searched but 10 percent may not have been searched, etc.).

1. <u>Rank Correlation</u>

The reason respondents were asked to rank rather than measure the importance of data retrieval system (DRS) characteristics is due to the difficulty of constructing an objective scale for such measurements. Even if importance was a measurable quality, it would not be sufficient to know that a respondent thought characteristic A to be 20 percent more

important than characteristic B without also knowing the equivalent of 100 percent on some objective scale.

There are two questions concerning rankings that can be answered by the methods developed (see Appendix A) in the theory of rank correlation.[7]

(1) What is the agreement, or concordance, among the individual rankings, and

(2) What is the "true" ranking of the performance characteristics.

It should be noted that a ranking does not tell how close the characteristics are on some scale. However, a ranking is unaltered if the scale is stretched. An example that illustrates these qualities is found in a track meet. The finishing order in a race is independent of the time scale used to measure the race. However, if the order in which the runners passed the finish line is all that is known, then it is not possible to determine how close the runners were to one another.

Table III summarizes the rankings obtained from 92 questionnaires. The rank totals are the totals of the numbers between 1 and 7 assigned to each characteristic. The smaller the sum, the more important the characteristic; therefore, the final ranking proceeds from the smallest sum to the highest.

Table III

RANKING BASED ON 92 QUESTIONNAIRES

Characteristic	Rank Totals	Final Ranking
A	231.0	1
B	466.0	7
C	292.5	2
D	373.0	4
E	390.0	5
F	456.0	6
G	367.5	3

Two different statistics for measuring rank correlation will be used in the remainder of the discussion. The first, the coefficient of concordance, W, is used when three or more rankings are compared. The second, the coefficient of rank correlation, τ, is used when two rankings are compared.

2. Test of Significance

The 92 respondents are a sample from a larger population; although it is of some interest to measure the relationship between document retrieval system characteristics and their importance to these 92 individuals, it is of much greater interest to be able to generalize the results to the parent population. This involves a test of the significance of the rank correlation statistic computed from the sample.

To test the significance of some sample statistic, the observed value of the statistic is compared to the entries in a frequency distribution of all values the statistic may take on. Each of the possible values in the frequency distribution has a certain probability of occurrence. If the probability that a random occurrence of the observed value of the statistic is sufficiently low (say 0.01), then it is possible to conclude that the observed value is significant. In the present context, a significant value of the coefficient of concordance implies agreement among the respondents in their ranking of retrieval system characteristics. In the following tests, rankings of retrieval system characteristics are said to agree if there is one chance in a hundred of attaining or bettering the observed value of the sample statistic (W or τ) by chance alone. The one percent significance level is commonly used in statistical tests. Methods for testing the significance of W and τ are discussed in Chapters 4 and 6 of Kendall's book.[7]

The value of the coefficient of concordance derived from the 92 responses is W = 0.1785. This value lies far beyond the one-percent significance point; that is, the probability of arriving at the observed or a greater value by chance is less than one in a hundred. On the basis of this test it is fair to conclude that there is agreement among the 92 rankings.

Study of Table III reveals that the chief reason for the significance of W is the almost universal agreement on the importance of characteristic A (the minimum time characteristic). This situation can be compared to ranking seven milers--Olympic champion Herb Elliot and six high school runners--on the basis of a series of test races. Even were the six high school milers equally matched, so that their finishing order was random, the fact that Elliot always came in first would tend to yield a significant coefficient of concordance over the observed trials.

The dominance of characteristic A is eliminated by computing and testing the significance of the coefficient of concordance computed for the six characteristics B-G. This was done and the value $W = 0.0683$ also proved significant at the one-percent level. In the remaining analysis the significance of W and τ is tested for characteristics A-G and τ for characteristics B-G. The letter "S" indicates significant agreement; the letters "NS," non-significance.

3. Ranking Within Categories

a. Ranking Within Companies

It seems reasonable to assume that the respondent's attitude about document retrieval system characteristics is conditioned by the retrieval system available to him. To test this assumption, the 92 rankings were grouped by company and the coefficient of concordance computed for the responses within each company. Table IV summarizes the calculations.

Table IV

RESULTS OF TESTS FOR AGREEMENT WITHIN COMPANIES

Company	Sample Size	Agreement at 0.01 Level: Characteristics A-G	Characteristics B-G
SRI	22	S	S
Sylvania	27	S	NS
IBM	18	NS	NS
Lockheed	25	S	S

Note that people within separate companies could not always agree among themselves as to the relative importance of the various requirements.

b. Ranking Within Job Classifications

Another interesting hypothesis was that there would be agreement on the rankings within different job classifications--that is, Research Managers would agree on what the important requirements are. To test this hypothesis, the 92 engineers were classified by their answers to Question 23 (Appendix F). The results are shown in Table V.

Table V

RESULTS OF TESTS FOR AGREEMENT WITHIN JOB CLASSIFICATIONS

Job Classification	Sample Size*	Agreement at 0.01 Level	
		Characteristics A-G	Characteristics B-G
Research Manager	17	S	NS
Senior Engineer	44	S	NS
Engineer	26	S	S
Junior Engineer	4	NS	NS

*One respondent did not classify his job.

From the test results, it appears that, aside from characteristic A, there is almost complete disagreement within all job classifications about the relative importance of retrieval system characteristics.

c. Ranking Within Academic Degree Groups

Another significance test was run on the 92 responses grouped by academic degree. The results for four categories are shown in Table VI. Within each academic degree there is complete agreement about the relative importance of the requirements when characteristic A is included. Without characteristic A, there is complete disagreement within each academic degree.

Table VI

RESULTS OF TESTS FOR AGREEMENT WITHIN ACADEMIC DEGREE GROUPS

Highest Degree Held	Sample Size	Agreement at 0.01 Level	
		Characteristics A-G	Characteristics B-G
BSEE	26	S	NS
MSEE	35	S	NS
Engineer	7	S	NS
PhD, ScD	14	S	NS

d. Ranking Within Author and Non-Author Categories

The amount of searching performed, and consequently the information requirements, may depend on whether the respondent has written any books, papers, or articles. To test this hypothesis, the concordance coefficient was computed for the rankings after the engineers were grouped into those that had published, and those that had not. The results are shown in Table VII.

Table VII

RESULTS OF TESTS FOR AGREEMENT WITHIN AUTHOR AND NON-AUTHOR CATEGORIES

Author Category of Respondent	Sample Size	Agreement at 0.01 Level	
		Characteristics A-G	Characteristics B-G
Did not publish	47	S	NS
Did publish	45	S	S

Both groups agreed within themselves when characteristic A was included. Otherwise, only the group of authors agreed.

e. Ranking Within Age Groups

It is possible that information requirements might depend upon the user's age; consequently, a test was run on the agreement within each age group. The results are shown in Table VIII.

Table VIII

RESULT OF TESTS FOR AGREEMENT WITHIN AGE GROUPS

Age Group	Sample Size	Agreement at 0.01 Level	
		Characteristics A-G	Characteristics B-G
25-29	21*	S	NS
30-34	27	S	NS
35-39	24	S	NS
40-44	16	S	NS
45 and over	3	NS	NS

*The group of under 25 years had only one member and was not considered further.

This test indicates that in this age group there is almost general agreement on rankings when characteristic A is included, and complete disagreement otherwise.

f. Ranking Within Specialty Fields

It was hypothesized that the rankings would be different within specialty fields. A test was run on the agreement within specialty groups and the results are shown in Table IX.

Table IX

RESULT OF TESTS FOR AGREEMENT WITHIN SPECIALTY FIELDS

Specialty Field	Sample Size	Agreement at 0.01 Level	
		Characteristics A-G	Characteristics B-G
Circuits and devices	40	S	NS
Microwave and communication	19	S	S
Antennas and propagation	9	S	NS
Communication theory	6	NS	NS
All others	18	NS	NS

There was some agreement within specialty fields when characteristic A was considered; otherwise there was generally disagreement within each specialty field.

4. Rankings Between Categories

Where there is significant agreement among the responses within a category, it is possible to compare rankings between categories.* For example, the employees at SRI agreed on the ranks assigned to the retrieval characteristics B-G. The same can be said of the Lockheed employees. Assuming the samples represent SRI and Lockheed worker attitudes, it is reasonable to test the agreement between (not within) the SRI and Lockheed rankings.

The following analyses are restricted to comparisons of those categories whose members agreed in their rankings of the retrieval system characteristics; i.e., categories in Tables IV-IX in which agreement at the 0.01 level is significant.

a. Rankings Between Companies

Table X shows the rankings of characteristics A-G derived from the various companies.

Table X

RESULT OF TESTS FOR AGREEMENT BETWEEN COMPANIES--CHARACTERISTIC A INCLUDED

Company	Characteristics						
	A	B	C	D	E	F	G
SRI	2	7	1	3	4	6	5
Sylvania	1	7	3	5	4	6	2
Lockheed	1	6	2	4	5	7	3
Consensus	1	7	2	4	5	6	3

The value of the concordance coefficient W = 0.865 is significant at the 0.01 level. A comparison of the rankings of characteristics B-G is shown in Table XI.

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*If the members of a category can not agree among themselves, there is no point in looking for agreement between this category and another.

Table XI

RESULT OF TESTS FOR AGREEMENT BETWEEN COMPANIES--CHARACTERISTIC A EXCLUDED

Company	Characteristics					
	B	C	D	E	F	G
SRI	6	1	2	3	5	4
Lockheed	5	1	2	4	6	3
Consensus	5.5	1	2	3.5	5.5	3.5

The coefficient of rank correlation has the value $\tau = 0.73$, which has three chances in 100 of being equalled or bettered by chance alone. This is not below the .01 level used to define significant agreement.

b. Rankings Between Job Classifications

Table XII shows the rankings of characteristics A-G derived from the various job classifications.

Table XII

RESULT OF TESTS FOR AGREEMENT BETWEEN JOB CLASSIFICATIONS

Job Classification	Characteristics						
	A	B	C	D	E	F	G
Research manager	1	7	4	2	5	6	3
Senior engineer	1	7	2	3	5	6	4
Engineer	2	6	1	5	3	7	4
Consensus	1	7	2	3	5	6	4

The coefficient of concordance $W = 0.825$ is significant at the 0.01 level. These three job classifications agree within themselves and between each other when characteristic A is included.

c. Rankings Between Academic Degree Groups

Table XIII shows the rankings of characteristics A-G by academic degree. The concordance coefficient W = 0.915 is significant at the 0.01 level.

Table XIII

RESULT OF TESTS FOR AGREEMENT BETWEEN ACADEMIC DEGREE GROUPS

Academic Degree	Characteristics						
	A	B	C	D	E	F	G
BSEE	1	6	2	5	4	7	3
MSEE	1	7	2	3	4	6	5
Engineer	2	7	1	3	5	6	4
PhD, ScD	1	7	2	4	5	6	3
Consensus	1	7	2	3.5	5	6	3.5

All the academic categories agree within themselves and between each other when characteristic A is included.

d. Rankings Between Author and Non-Author Categories

The author, non-author rankings are shown in Table XIV.

Table XIV

RESULT OF TESTS FOR AGREEMENT BETWEEN AUTHOR AND NON-AUTHOR CATEGORIES

Author Category	Characteristics						
	A	B	C	D	E	F	G
Did not publish	1	6	2	3	5	7	4
Did publish	1	7	2	4.5	4.5	6	3
Consensus	1	6.5	2	4	5	6.5	3

The value of the coefficient of rank correlation is $\tau = 0.878$, which is significant at the 0.01 level. These two categories agree within themselves and between each other when characteristic A is considered.

c. Rankings Between Age Groups

The rankings between the four age groups are shown in Table XV.

Table XV

RESULT OF TESTS FOR AGREEMENT BETWEEN AGE GROUPS

Age Group	Characteristics						
	A	B	C	D	E	F	G
25-29	1	6	2	5	3	7	4
30-34	1	7	2	3	5	6	4
35-39	1	7	2	4.5	4.5	6	3
40-44	1	7	2	4	6	5	3
Consensus	1	7	2	4	5	6	3

The concordance coefficient is W = 0.905, which is significant at the 0.01 level. The members of these age groups agree within themselves and between each other when characteristic A is considered.

f. Ranking Between Specialty Fields

The rankings between three specialty groups is shown in Table XVI.

Table XVI

RESULT OF TESTS FOR AGREEMENT BETWEEN SPECIALTY FIELDS

Specialty Field	Characteristics						
	A	B	C	D	E	F	G
Circuits	1	7	2	3	5	6	4
Microwave	1	6.5	2.5	5	4	6.5	2.5
Antennas	1	7	2	4	5	6	3
Consensus	1	7	2	4	5	6	3

The value of the concordance coefficient W = 0.94 is significant at the 0.01 level. These three specialty fields agree within themselves and between each other when characteristic A is included.

5. General Comments About the Rankings

In general, there is disagreement about the relative importance of Characteristics A-G. Even though a composite ranking was obtained (Table III) further analysis showed that there was disagreement within nearly every sub-group of the sample population. In only two of the six breakdowns (grouping by academic degree and by author vs. non-author) did each of the sub-groups of that breakdown agree within themselves--and this was when Characteristic A was included. When Characteristic A was excluded, there was disagreement within at least one sub-group of each breakdown, and in two breakdowns (grouping by academic degree and by age) there was disagreement within every single sub-group of those breakdowns. Sub-groups with internal agreement always had substantial agreement between them.

One thing seems certain as a result of this ranking study: Characteristic A (minimum time to obtain the major group of relevant references) seems to be very important to all of the users. It is also clear that the users are generally uncertain and in disagreement about the relative importance of the remaining characteristics. Further studies of relative rankings should give some attention to finding ways of incorporating greater resolution and accuracy in the measurements, and of improving the list of requirements.

V A GENERAL FUNCTIONAL MODEL OF AN INFORMATION RETRIEVAL SYSTEM

A. The Need for a Model

A model is a useful tool for describing phenomena of interest. It provides a means by which a phenomenon can be reduced to its basic elements, thus simplifying subsequent exploration and analysis. It may also serve as a useful intellectual exercise, compelling the researcher to check that all significant points have been considered in his analysis. Most important, it serves as the framework for analytical or simulation studies of the system.

Simulation techniques can be profitably used to predict the performance of an information retrieval system under a variety of operating conditions and for a variety of system configurations. In this way, proposed retrieval systems can be studied to determine costs and performance, without actually installing or operating such systems. Although there are limits to the results that can be achieved by simulation, it appears that no extensive simulation experiments have been made to date for information retrieval systems. Section VI describes some studies in which the operation of several retrieval systems was simulated over wide ranges of operating parameters, using the model described in the following pages, in order to determine the operating cost for particular problems.

In only a very few cases does a simulation model truly represent the behavior of the actual system, and in only a few cases can it be extended or generalized to describe all similar systems. The model described below was designed to represent the operations of an information storage and retrieval system. It is general enough to be applied to a spectrum of systems, from edge-punched cards to large retrieval systems that utilize computers or other complicated digital equipment. Although the model is not so general that it can include <u>any</u> retrieval system one may elect to consider, it can be modified to include additional features.

B. Description of the Model

The model shows, in general form, all of the operations required to establish, operate, and maintain an information retrieval system. It is divided into seven different parts, each of which is relatively independent. The seven parts of the model, illustrated in flow chart form in Figs. 1 through 7, are:

(1) System conversion or establishment

(2) Acquisitions

(3) Input

(4) Search

(5) Maintenance of the indexing information

(6) Re-file or return borrowed material

(7) Handling document requests and inter-library loan.

The model was also used as a basis for the cost analysis programs described in Sec. VI.

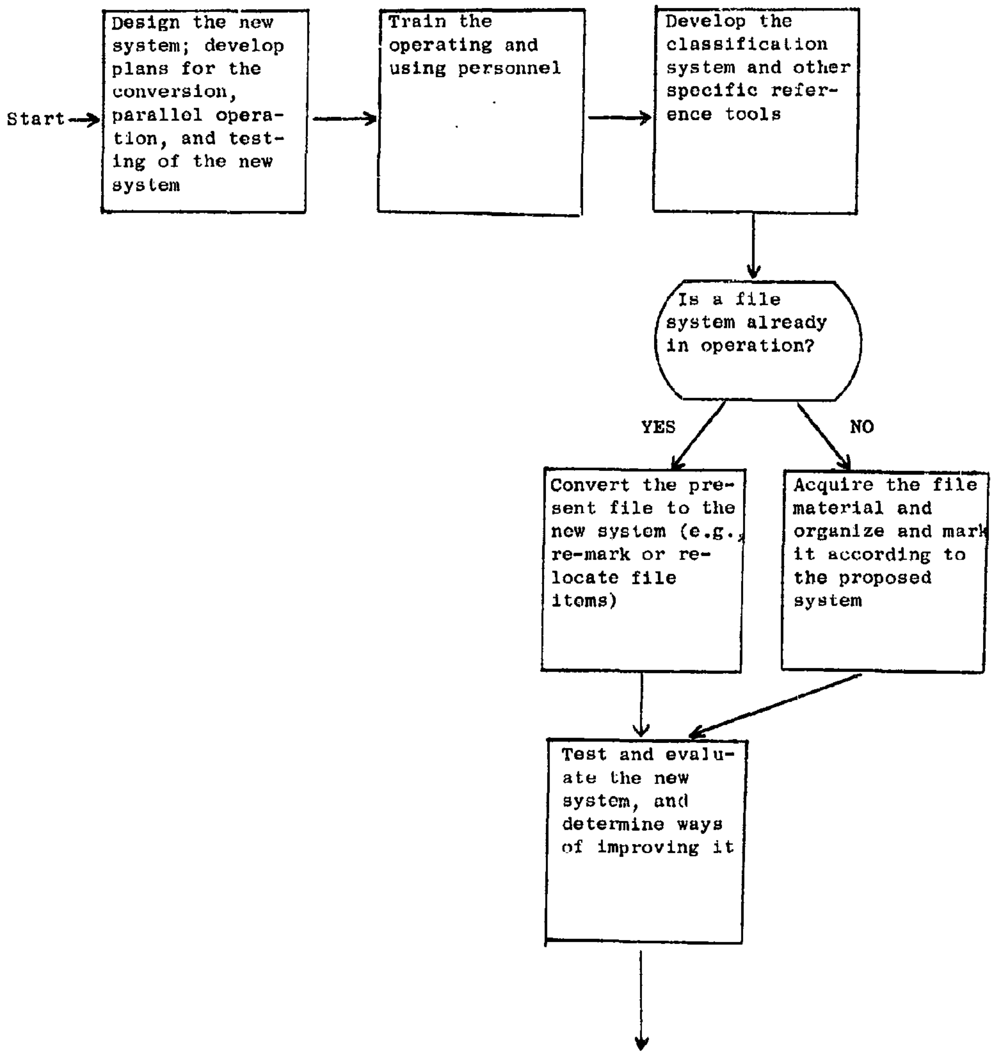

FIG. 1 FLOW CHART FOR SYSTEM CONVERSION OR ESTABLISHMENT

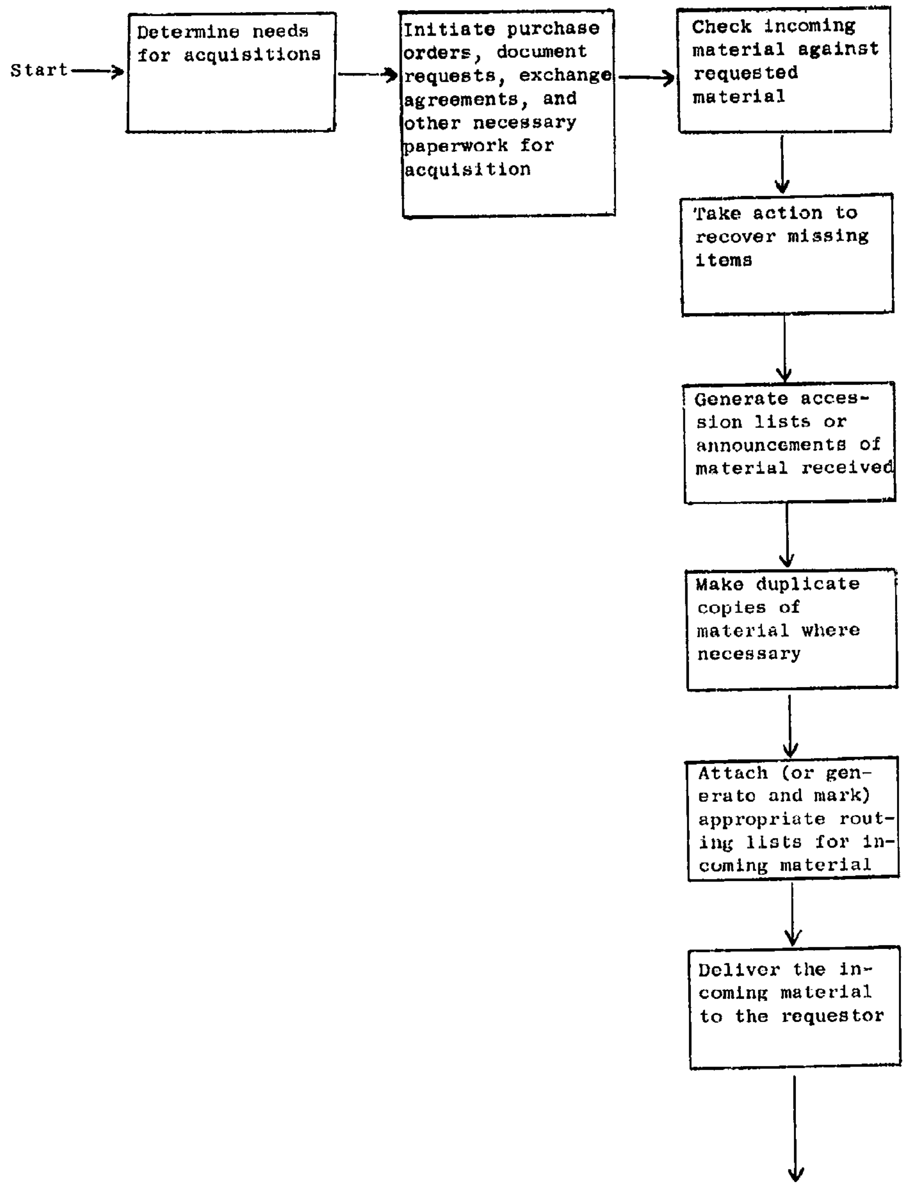

FIG. 2 FLOW CHART FOR ACQUISITIONS

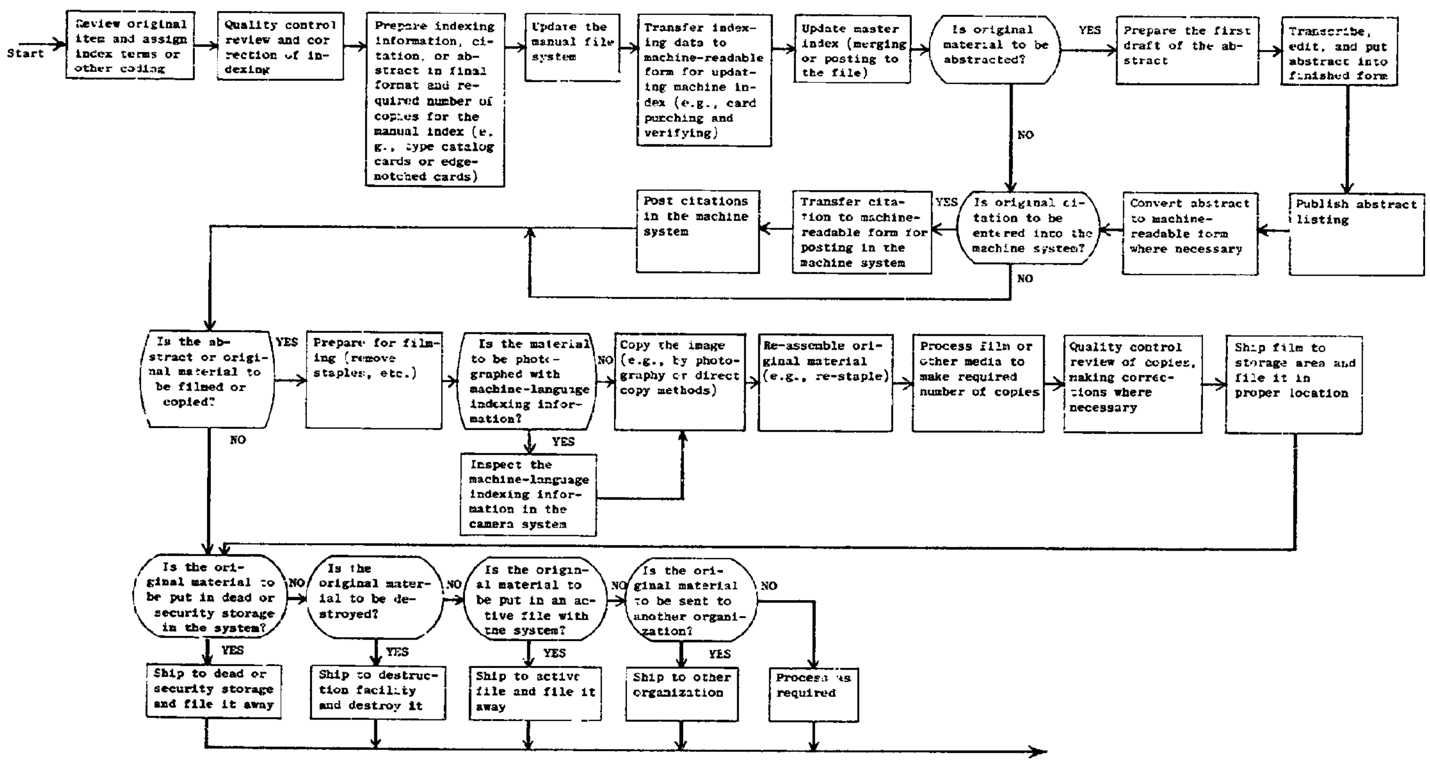

FIG. 3 FLOW CHART FOR INPUT

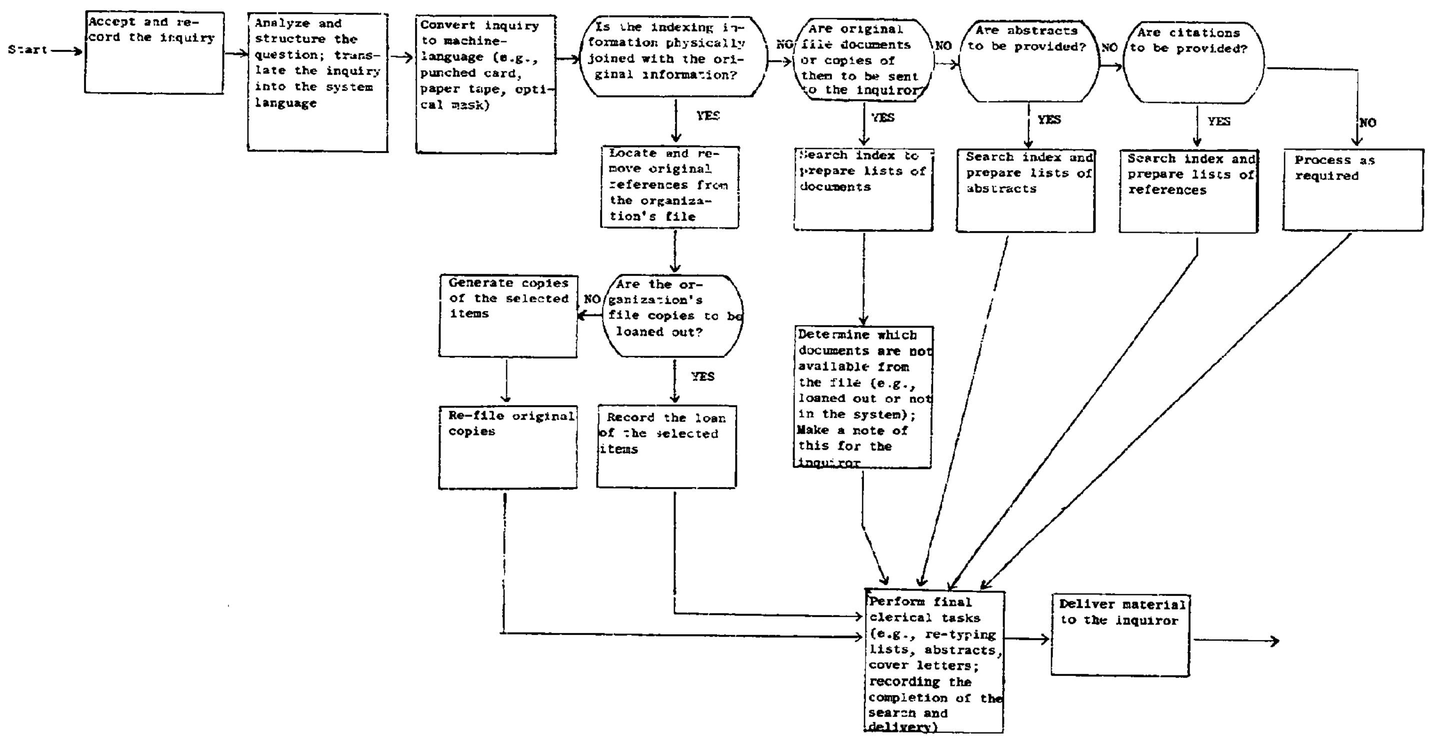

FIG. 4 FLOW CHART FOR SEARCH

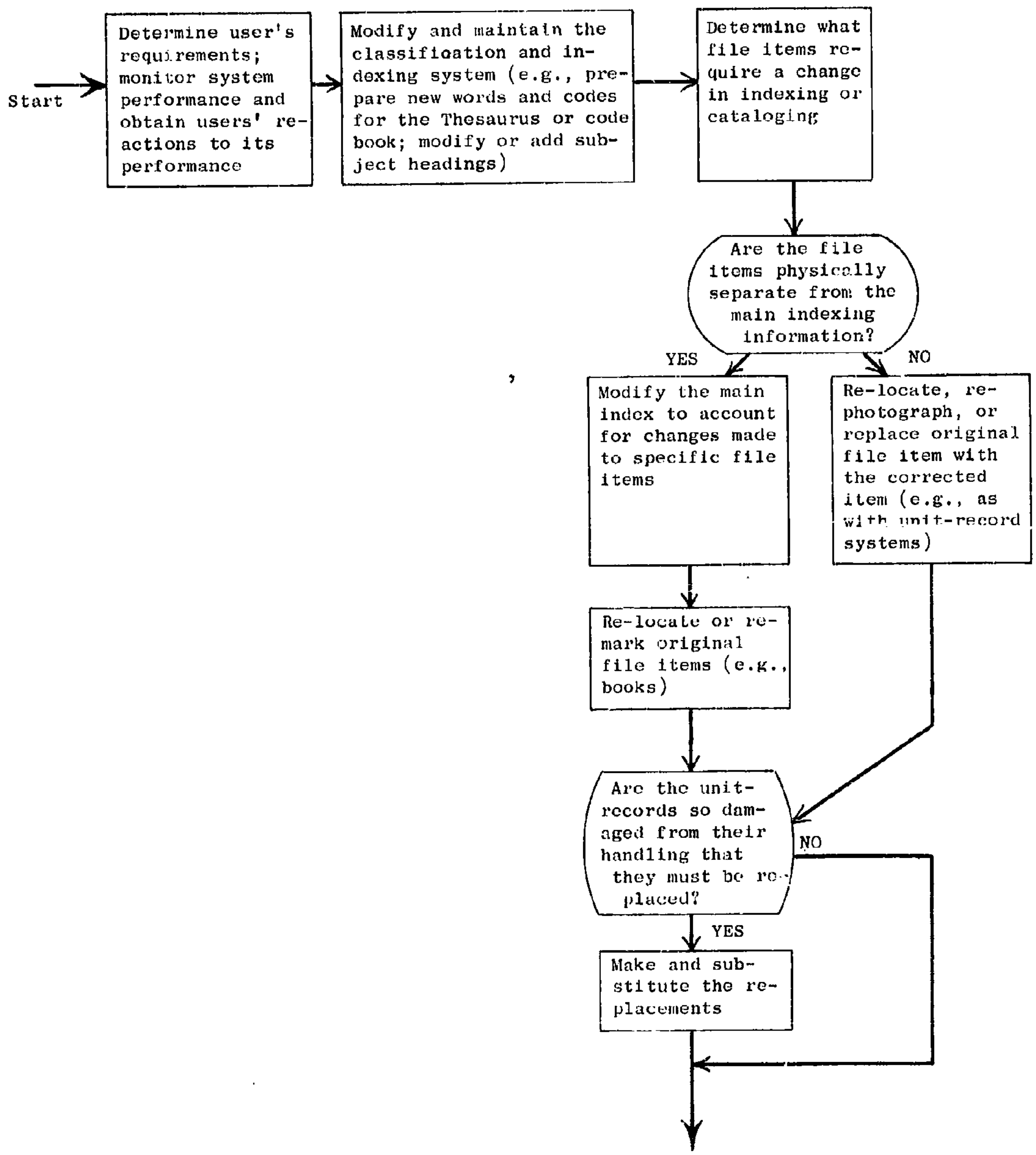

FIG. 5 FLOW CHART FOR MAINTENANCE OF THE FILE AND INDEXING INFORMATION

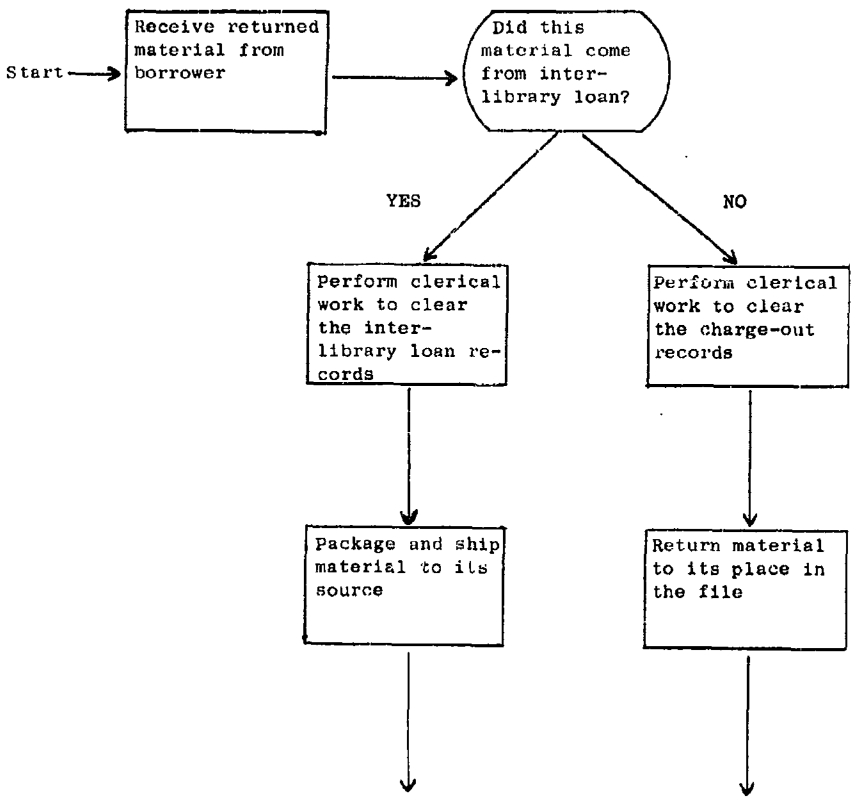

FIG. 6 FLOW CHART FOR RE-FILE OR RETURN BORROWED MATERIAL

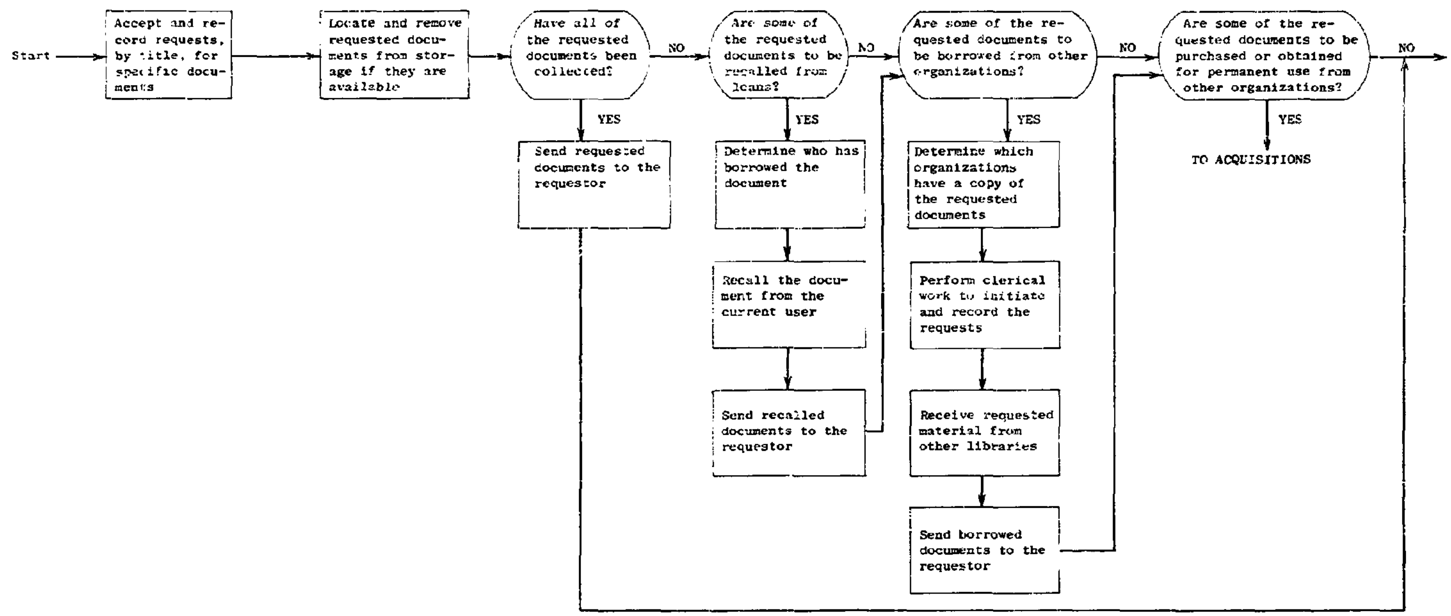

FIG. 7 FLOW CHART FOR DOCUMENT REQUESTS AND INTER-LIBRARY LOAN

VI EVALUATION TECHNIQUES

A. General

As stated in the Introduction, the actual evaluation procedure utilizes three complementary tools: (1) basic criteria or screening procedures to describe the range of some requirements encountered in operating installations; (2) one or more comprehensive evaluation procedures that determine how well the performance of a given system satisfies the requirements of a particular population of users; (3) two cost analysis programs that determine the equivalent annual operating costs of a retrieval system given a description of its functional characteristics. These three tools are described in more detail in the following sections.

B. Preliminary Screening for Ranges of Requirements of Information Retrieval Systems

A number of equipment manufacturers and some librarians have suggested the possibility of developing "universal" information retrieval systems that could generally be applied to any problem. In order to test any claims of universality, some data must be available to describe the range and distribution of the parameters of the "universal" problems. To be completely universal, a proposed system would have to be able to accept or adapt to wide ranges in the file size, accession rate, search volume, search response times, indexing complexity, cost, type of file material, and many other parameters in order to accommodate the practical range of real problem situations that exist. This section of the report provides some information about the distributions of a few problem parameters, in order to allow some estimates to be made of the degree of universality of proposed retrieval systems. Only a few problem parameters have been studied, but it should not be too difficult to describe the distributions of additional parameters with a moderate amount of effort.

Proponents of a semi-universal system might consider applying it to specific types of organizations or to specific subject fields. An example of the first type would be a proposal for a system for college and

university libraries, or for public libraries. An example of the second type would be a proposal for a system for the handling of all the literature in any one field of science or technology. Some background information to assist in the evaluation of such general proposals is given in Figs. 8, 9, 10, and 11.

Figure 8 portrays the current file size and accession rate* of each of the U.S. college and university libraries and provides information on the cumulative distributions of these parameters. It shows, for example, that to be applicable to 90 percent of the U.S. college and university libraries, a universal system would have to have the storage or indexing capacity for at least 200,000 file items, and the capability for accepting the input of at least 200 new file items per week without developing a backlog.

Figure 9 portrays the same type of information for the U.S. public library systems.** It shows, for example, that to be applicable to 90 percent of the U.S. public libraries, a universal system would have to have the storage or indexing capacity for at least 500,000 file items, and the capability for accepting the input of at least 630 new file items per week without developing a backlog.

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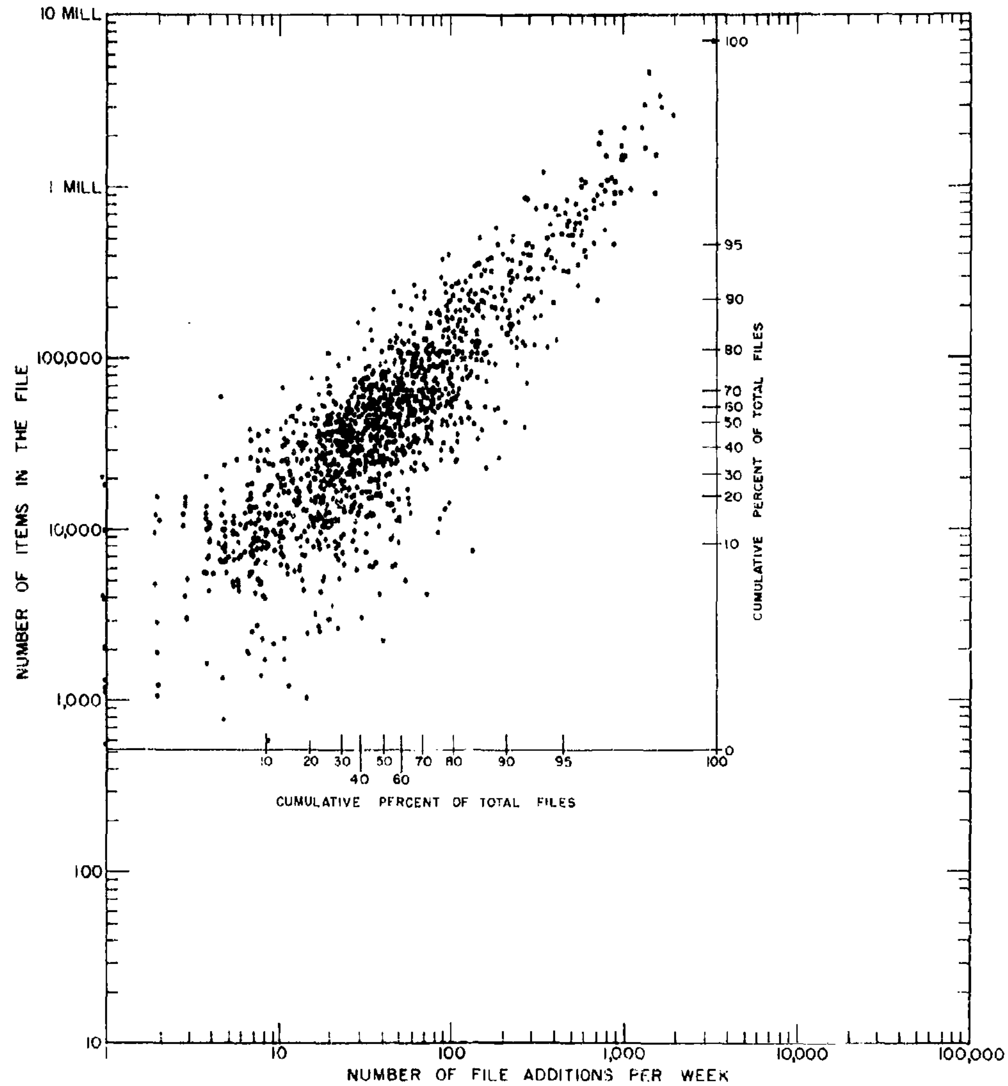
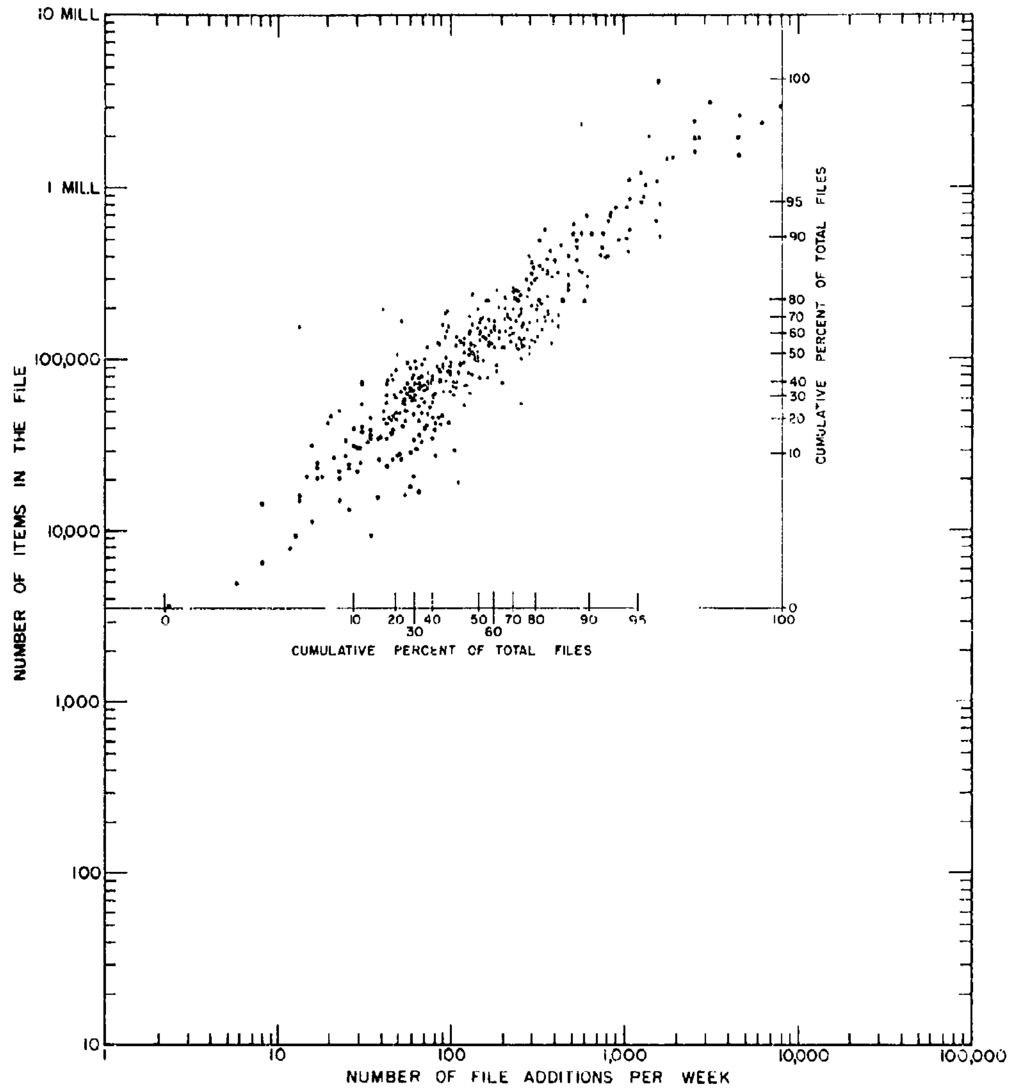
*For the purposes of this study, a file item was defined as any printed, typewritten, mimeographed, or processed work, bound or unbound, that has been fully catalogued or fully prepared for use. Microcards, microfilms, and other forms of microtext are included. The accession rate is defined as the actual number of file items acquired, and does not consider the file items withdrawn or purged from the file.

**The public library systems in this case are defined as collections of individual libraries working together cooperatively in one city (e.g., The San Francisco Public Library System). Presumably the control of each of these library complexes is centralized enough to consider each single library system as a candidate for a single information retrieval system--and not consider applying retrieval systems to individual libraries.



SOURCE: LIBRARY STATISTICS OF COLLEGES AND UNIVERSITIES, 1959-60, PART I : INSTITUTIONAL DATA, U.S. DEPT OF HEALTH, EDUCATION AND WELFARE, OFFICE OF EDUCATION, J.C. RATHER AND D.C. HOLLADAY, REPORT OE-15023 (1961)

FIG. 8 U.S. COLLEGE AND UNIVERSITY LIBRARIES – FILE SIZE AND ACCESSION RATES



SOURCE. 1. STATISTICS OF PUBLIC LIBRARY SYSTEMS IN CITIES WITH POPULATIONS OF 100,000 OR MORE : FISCAL YEAR 1958, U.S. DEPT OF HEALTH, EDUCATION, & WELFARE; OFFICE OF EDUCATION, CIRCULAR 590 (JUNE 1959).
2. STATISTICS OF PUBLIC LIBRARY SYSTEMS IN CITIES WITH POPULATIONS OF 50,000 TO 99,999, FISCAL YEAR 1958, U.S. DEPT. OF HEALTH, EDUCATION, & WELFARE; OFFICE OF EDUCATION, CIRCULAR 594 (JULY 1959).
3. PUBLIC LIBRARY STATISTICS: 1944-45 (FOR CITIES WITH POPULATIONS OF 25,000 TO 49,999), FED. SECURITY AGENCY; OFFICE OF EDUCATION (1947)

FIG. 9 U.S. PUBLIC LIBRARY SYSTEMS – FILE SIZE AND ACCESSION RATES

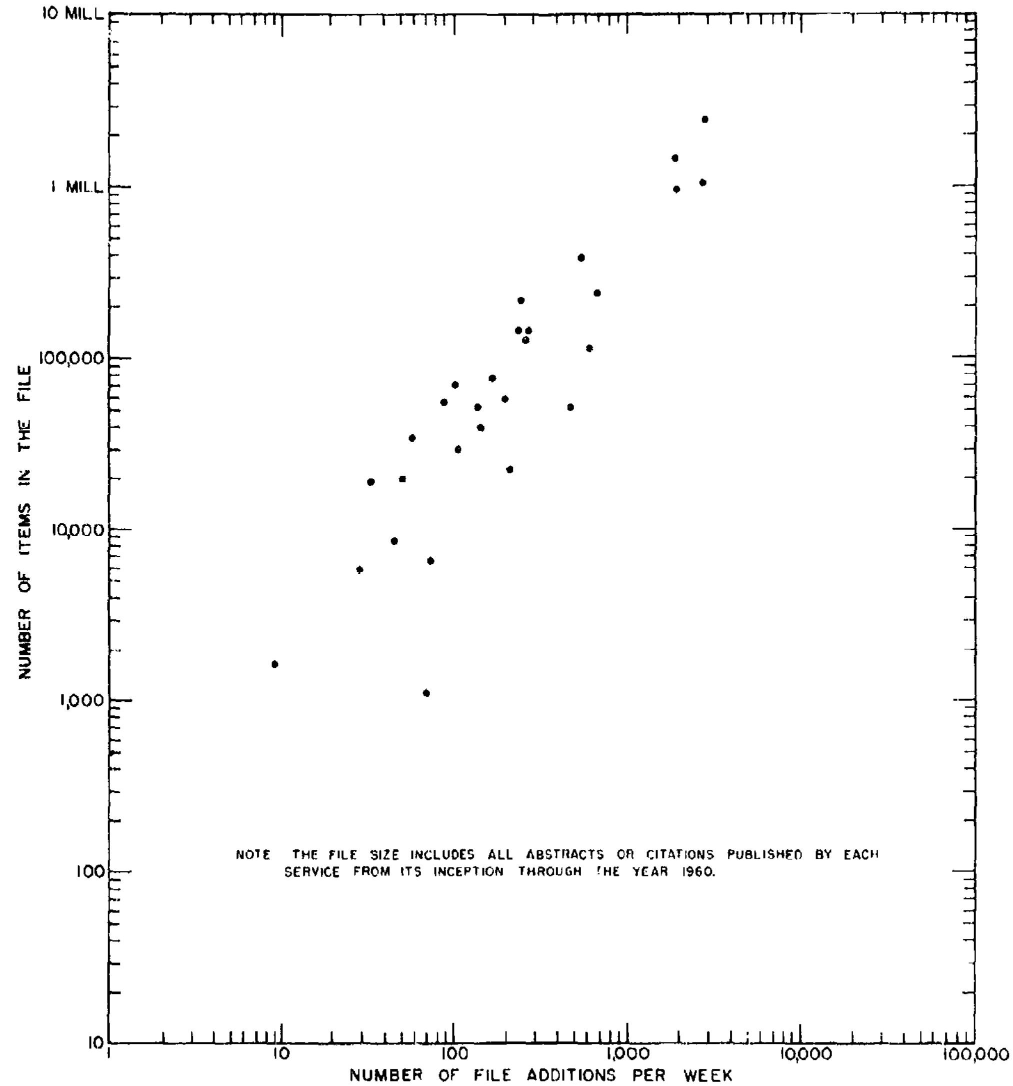


FIG. 10 ACCUMULATED FILE SIZES AND CURRENT ACCESSION RATES OF THE PUBLICATIONS OF SEVERAL ABSTRACTING AND INDEXING SERVICES

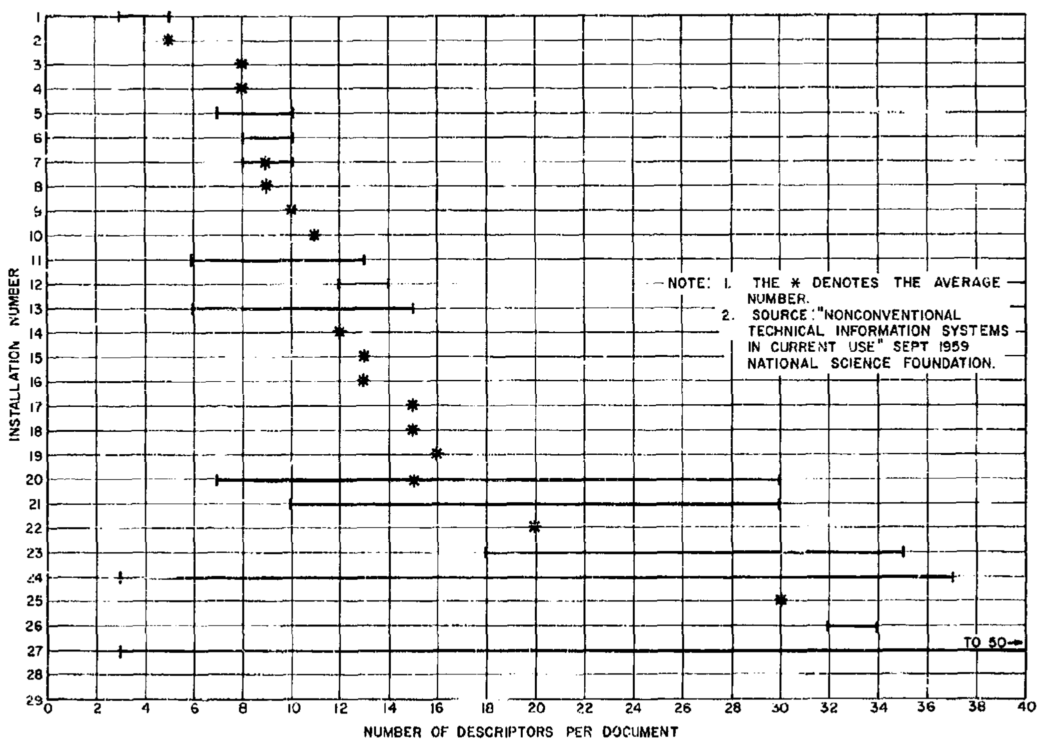


FIG. 11 RANGE OF SYSTEM REQUIREMENTS FOR THE NUMBER OF DESCRIPTORS PER DOCUMENT

Some data was collected to describe the file size and accession rates of industrial research libraries of different types, but it was not complete enough to allow the same type of definitive statements to be made as were made for the university and public libraries.

Proposals have been made for establishing mechanized literature searching systems for the files of the existing abstracting and indexing services. It is not completely unreasonable to suggest that a new reference center for the publishers of such publications as Chemical Abstracts, Index Medicus, or the Review of Metal Literature might consider encoding and including all of the citations or abstracts that had ever been prepared by them, to include in a file for searching. For that reason, data were collected to describe the total warehouse of citations or abstracts that had ever been published by each of several indexing and abstracting services, to show the amount of storage or indexing capacity that would be required of a system universally applicable to all such services.[8] Data were also collected to describe the required accession rates, and are shown in Fig. 10. No cumulative distributions are shown since the data for many more services was not available. However, any universal system prepared to accommodate the files of all of the indexing and abstracting services would require a storage or indexing capacity of at least 2.6 million items, and a capability for accepting the input of at least 2,900 new file items per week without developing a backlog. Appendix E gives the identities and exact figures for the data shown in this figure.

The indexing and abstracting services do not represent the total volume of literature that might be included in a retrieval system since they are usually restricted in their degree of coverage by their budget and other considerations. Some data indicate, for example, that to handle the entire volume of periodical literature for the fields of medicine, agriculture, chemistry, and the biological sciences might require a capability for accepting, indexing, and storing an input of approximately 220,000, 150,000, 150,000, and 150,000 file items per year, respectively.[8]

From an indexing standpoint, a universal retrieval system would have to accommodate a large variety of indexing systems, each of which could be implemented with varying degrees of complexity. It must lend itself to the use of classification and indexing systems such as the following: hierarchical schemes such as the Universal Decimal, Dewey Decimal, and the Library of Congress classification schemes; a variety of coordinate indexing systems and their variations such as Uniterms, links and roles, descriptors, and keywords; faceted classification schemes such as those proposed by Ranganathan, Vickery, and others; and more complex systems such as the Perry-Kent system of telegraphic abstracting and indexing. One brief illustration of the indexing capability required of a universal system is given in Fig. 11, which shows the range of descriptors or Uniterms required for each file item in a number of actual installations using this type of indexing.[9] These data suggest that such a system would require the capability for implementing a coordinate indexing system with at least 50 descriptors per file item.

Hopefully, the preceeding discussion provides a preliminary basis for accepting or rejecting claims of the universality of proposed retrieval systems. The next sections describe more comprehensive evaluation techniques that have been developed for the analysis of retrieval systems proposed for specific applications.

C. General Performance Evaluation

Two approaches were developed to obtain a measure of how well any specific information system satisfies the requirements of the users. The first method matches the measured performance with the requirements, applies weighting factors to each requirement, and determines an overall figure of merit. The second method utilizes a model which attempts to reduce all the requirements and performance statements to the common denominators of time or cost. Both of these methods are described in more detail below.

1. Performance-Requirement Matching with Weighting

This procedure was developed as an interim tool to provide rough performance evaluations. It could be extended to become a more useful tool; however, it does have the disadvantage of relying, to a certain measure, on opinions of the users.* There is also another fundamental problem that poses a stumbling block, and that is the question of developing weighting factors that describe the relative importance of each of the system requirements. This problem is discussed in more detail at the end of the description of the first performance evaluation procedure.

This procedure develops a measure of how well any specific information system satisfies the users' requirements by matching the measured performance with the requirements, and applying proper weighting factors. Certain basic information about the system and the users (shown in general form in Fig. 12) is needed for this evaluation:

(1) A list of factors or considerations that are normally called "user requirements" (e.g., required response time and false drop rate) should be developed. There is no fundamental restriction on the sequence or the number of requirements that can be entered on this list, although to simplify the measurements and computation the list may, in practice, be held to about ten or twelve entries. There is the possibility that once a master list of requirements has been established and tested, it may be useful as a standard for subsequent evaluations.

(2) A measure of the relative importance of each of the requirements should be obtained from the users to be served by this system. That is, a weighting figure

*This is discussed further in the subsequent description of the second performance evaluation method.

REQUIREMENT	MEASURED USER REQUIREMENTS	MEASURED SYSTEM PERFORMANCE	MEASURE OF AGREEMENT BETWEEN PERFORMANCE AND REQUIREMENT	RELATIVE IMPORTANCE OF THIS REQUIREMENT	SCORE FOR THIS REQUIREMENT
1. Tolerable delay in receiving the final search product	100%, 0; 0 t → 6 mos.	100%, 0; 0 t → 6 mos.	M_1	W_1	M_1W_1
2. Tolerable fraction of relevant material overlooked during the search	100%, 0; 0 100%	100%, 0; 0 100%	M_2	W_2	M_2W_2
3. Desired form of search product	100%, 0; entire doc. abstr. ref. serial no.	100%, 0; entire doc. abstr. ref. serial no.	M_3	W_3	M_3W_3
4. Tolerable expenditure of effort by the user to communicate with the system	100%, 0	100%, 0	M_4	W_4	M_4W_4
5. Tolerable fraction of irrelevant material provided with the search product	100%, 0; 0 100%	100%, 0; 0 100%	M_5	W_5	M_5W_5
6. Desired currency or minimum age of file contents	100%, 0; 0 t → 10 yrs. old	100%, 0; 0 t → 10 yrs. old	M_6	W_6	M_6W_6
7. File size required to answer search requests	100%, 0; 1000 10 mill.	This system has no limit on file size	M_7	W_7	M_7W_7
- --	--	--	--	--	--
- --	--	--	--	--	--
- --	--	--	--	--	--
N. Final requirement	--	--	M_n	W_n	M_nW_n
				TOTAL SCORE	$\sum_{i=1}^{n} M_iW_i$

Note: (1) The vertical scale on the plots of user requirements refer to the fraction of users with that requirement.

(2) The vertical scale on the plots of system performance refer to the fraction of searches with that performance.

FIG. 12 WORKSHEET FOR PERFORMANCE EVALUATION – GENERAL CASE

for each requirement should be obtained that reflects the relative importance of that requirement to the users being served. It is quite likely that different groups of users will rank or weight the requirements differently. However, after enough measurements have been made of representative user groups, it may be possible to arrive at empirical rule-of-thumb weightings or design guidelines that could be used for most subsequent evaluations. The weightings would also be useful to equipment and system designers, to aid in the development of systems that more nearly satisfy the users' problems.

(3) For each requirement listed, measurements should be made to quantitatively describe the users' requirement. For some requirements (e.g., the ease of communication with the system) it may be extremely difficult or impossible to obtain any measurements, and consequently it will be impossible to measure how well the system satisfies the user requirement. But although one can not obtain a quantitative measure of how well the proposed system satisfies this requirement, the analyst will at least know the relative importance of this requirement and can treat it separately. In the same manner as the users weighting of the requirements, the actual measurements of the requirements may differ among different groups of users. However, there is the possibility, just as with the requirement ranking, that after enough measurements have been taken from representative groups, it may be possible to arrive at general guidelines or standards that could be adapted for subsequent evaluations, thus eliminating the need for more measurements. The measurements and rankings of the requirements could be used as specifications or design goals for the equipment and system designers.

(4) For each requirement listed, the proponent of each candidate system being evaluated must provide data to describe its performance for this particular parameter. To simplify the evaluation, these data should be in the same form as the measurements of the user requirements--that is, the same coordinates and scales.

The evaluation procedure then consists of the following operations (see the sample worksheet in Figure 12) for a given candidate system:

(1) For the first requirement on the list, determine the measure of agreement between the system performance and the user requirement. The detailed procedure for obtaining this measure of agreement is given in Appendix B.

(2) For the same requirement, multiply the measure of agreement by a weighting coefficient that represents the relative importance of that requirement, and record the resulting score for this requirement.

(3) Repeat the first two steps for each of the requirements on the list. When these operations have been performed on all of the requirements, then add up all the weighted scores to arrive at the total score--which is a single figure of merit.

The actual performance of any system will depend to a certain extent upon parameters such as the file size, the accession rate, and the volume of search requests. Consequently, the performance figures given for a specific analysis may not be applicable to the entire range of variations in the operating environment. It is also unlikely that any single figure of merit will have the same value for all different operating environments. For this reason, it may be advantageous to compute a set of performance figures for different sets of environments

so that a candidate system's evaluation can take place over a range of operating situations. It might be useful to compute and display a set of performance evaluations in a manner similar to the cost analysis procedure* described in a subsequent section.

2. Performance Evaluation With a Time-Cost Model

The first procedure could be implemented now, on an interim basis. Although this second procedure would require considerably more development before it can be useful, it does show promise as an evaluation procedure. One major objection to the first procedure is the weakness that, to a certain extent, it measures user requirements by sampling opinion. We ask the user to select from a limited number of choices, values of certain characteristics that in some sense satisfy his needs--instead of formulating document retrieval system models that tie user requirements and system characteristics to service and cost. Opinion sampling is often the only way of proceeding where information cannot be obtained analytically. However, where an analytical approach is possible, opinions should be subordinated to facts (i.e., a poll of stock clerks is not a valid basis for designing an inventory control system). A model of the system should still be constructed, but it should be a model from which we could derive optimal procedures.

During the course of this project, we have developed a framework for describing a document retrieval system in terms of cost and service. Although there are many formidable problems involved in applying this model, it is felt to be structurally sound. Its inputs are measurements of performance and costs rather than the opinions of potential users. A preliminary description of this approach is given in a subsequent section of this report.

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*See Fig. 16, p. 73, for an illustration of such a display.

3. Comments on the Performance Evaluation Procedures

For immediate and rough measures of performance, the first method and its associated interview guide would appear to be the most appropriate. For future evaluations, the second method with further development might be more appropriate. Neither method has been tested with representative systems, and both could use considerably more study and development.

D. Cost Analysis

1. General Form

One of the early plans of this project was to develop a computer program to take the model flow charts (Figs. 1 through 7) and all the necessary accompanying information to describe the labor, equipment, material, and other requirements for each of the functional boxes shown in the flow charts--and simulate the operation of defined information systems. However, because of the short duration of the project and the unavailability of the necessary time and cost information for most of the basic operations shown on the charts, it was necessary to resort to a much simpler program. As actually written and used, the program accepts summary statements about each of the seven basic parts and uses this information to compute an annual operating cost for the system under study. For analysis purposes, the flow charts are studied in the context of the particular system being studied, and serve as a checklist and a worksheet. Blocks on the charts that do not apply to the system being studied are crossed out, and the remaining blocks are studied by a knowledgeable person to determine the labor, equipment, and material required to perform that function.

The present program accepts the following input data for subsequent processing:

Cost figures

(1) Wage rates for each of 20 different labor categories

(2) Purchase or lease costs for each of 40 different pieces of equipment (first, second, and third shift costs)

(3) Material costs for each of 20 different types of materials

(4) Costs for each of 20 miscellaneous items

Cost functions

(1) Statements that are functions of the file accession rate

(2) Statements that are functions of the volume of search requests

(3) Statements that are functions of the miscellaneous relationships

Constants

(1) Initial file size

(2) Amortization period

(3) Rate-of-return to be used for amortization calculations

(4) Burden percentage

(5) Overhead percentage.

The present program assumes that a whole number of people will be used, so that each fraction of a type of laborer is rounded off to the next higher integer. Each particular type of laborer (e.g., clerk) works on any task that requires that labor type. Similarly, only whole numbers of equipment units will be used, so that the program will always charge the full cost of one computer, even though the computer may only be required for two hours per day.

Using the statements about the amount of each type of labor required to process the input items, conduct the searches, and perform

all the other necessary tasks, the program determines the total amount of each type of direct labor required. The program then estimates the amount of each type of indirect labor required, such as managers. At present, the program adds a manager when the total working staff reaches 5 persons, and adds an assistant manager for each increment of 20 persons after that. The salaries of all the direct and indirect labor types are then totaled to determine the basic labor charge. The burden (allowances for vacation, sick leave, social security, etc.) and the overhead charges are then used in a standard accounting manner to arrive at the total loaded labor costs.

Next, the equipment requirements are determined, based on the capacity of each of the individual units of equipment. The program accepts each piece of equipment on a lease or purchase basis--as defined by the input data. Lease charges are considered to be a simple monthly cost. Purchased equipment is amortized over a time interval and at an interest rate specified by the input data.[10] To simplify the program, the annual rate of return was divided by 12 to get a nominal (not effective) monthly rate of return which was then used to determine a uniform monthly payment. If the rate of return is set at zero percent, as done in most cursory economy studies, then the cost of the equipment is simply divided equally among the specified time intervals without considering the time value of money.

After the material and other miscellaneous costs are determined, a final total is obtained, on a monthly basis, for the entire system. An annual total is then determined, and this is the figure that is printed out by the computer. This set of computations has been done for a prescribed initial file size and a specified accession rate and volume of search requests. The computations are then repeated, using different sets of accession rates and search volumes as prescribed by the input data, to prepare the remaining entries for the printed table.

It might also be mentioned that the initial file size is growing at the prescribed monthly accession rate. Consequently, the labor and equipment costs usually increase for each subsequent month's operation.

It was primarily for this reason, and to make the analysis as realistic as possible that costs were computed on a monthly basis and then totaled for the year. For each month, the computations use the total file size that had accumulated at the beginning of that month.

Many of the procedures, such as the method of accounting for overhead charges, were built in as a part of the main program. However, it would be relatively simple to modify or change these procedures if necessary.

An evaluation of three representative information systems was made with this program. The computer presentation of the results is a table of the form shown in Figs. 13 through 15. It is useful to plot these results in the form shown in Fig. 16 to allow a direct comparison to be made of the economics of candidate systems over wide ranges in operating parameters. The sample comparison shown in Fig. 16 illustrates which system, from an economic viewpoint, is most favorable over a given operating region. With this program, relatively accurate cost analyses of proposed systems can be made without actually implementing a full-scale or pilot operation of the proposed system. In addition to serving as part of an evaluation procedure for proposed retrieval systems, the model can also be used effectively as a research tool to determine the effects of varying the parameters and over-all system design. It can also be used to test proposed systems that have no counterpart in any existing installation.

It is not our intent in Fig. 16 to show that one system is better than another. For this reason, we have omitted any detailed description or identification of these systems in this report. Considering the preliminary nature of our time and performance data, comparison would be unfair to all three systems. We merely want to demonstrate that evaluation procedures were developed that could produce this type of information. The credibility of the analysis depends in large measure on the accuracy of the basic time and cost data--which accuracy in our sample evaluations is highly suspect. It is quite possible that a system of pre-determined times for standard elemental

COST CALCULATIONS (IN DOLLARS PER YEAR)

EDGE-NOTCHED CARD SYSTEM
INITIAL FILE SIZE
RATE OF RETURN .070
AMORTIZATION PERIOD 5.00
BURDEN RATE .150
OVERHEAD RATE .250

INPUT RATE (ITEMS/MO.)	SEARCH VOLUME (NUMBER OF SEARCHES PER MONTH)								
	0.	10.	50.	100.	250.	500.	750.	1000.	2000.
0.	15691.	15691.	15691.	15691.	15691.	24662.	57840.	66811.	106380.
50.	1570[illegible].	15705.	15711.	15717.	15738.	28364.	57954.	70580.	118730.
100.	1571[illegible]	15719.	15730.	15744.	24755.	30042.	60640.	72810.	124717.
5000.	14351[illegible]	146746.	157154.	170285.	219145.	295339.	384376.	451069.	753634.
10000.	28166[illegible]	284504.	305799.	331531.	410264.	550452.	689102.	829810.	1393517.
15000.	40450[illegible]	413213.	444904.	483752.	610348.	814048.	1015648.	1221489.	2029445.
20000.	529763	538580.	580162.	632119.	808818.	1069193.	1337451.	1605198.	2678330.
30000.	790755.	805552.	866868.	945072.	1187083.	1574495.	1970823.	2367152.	3953636.
35000.	913607.	933232.	1005453.	1104775.	1377162.	1837536.	2299517.	2759896.	4594064.
40000.	1038861.	1059650.	1142261.	1245132.	1563789.	2089284.	2604200.	3142583.	5242878.

FIG. 13 COST CALCULATIONS FOR EDGE-NOTCHED CARD SYSTEM A - GENERAL CASE

COST CALCULATIONS (IN DOLLARS PER YEAR)

COMPUTER SYSTEM A
INITIAL FILE SIZE
RATE OF RETURN .070
AMORTIZATION PERIOD 5.0
BURDEN RATE .150
OVERHEAD RATE .250

SEARCH VOLUME (NUMBER OF SEARCHES PER MONTH)

INPUT RATE (ITEMS/MO.)	0.	10.	50.	100.	250.	500.	750.	1000.	2000.
0.	364668.	364669.	364675.	364682.	364703.	36473[illegible]	379915.	379951.	410376.
50.	364673.	64675.	364680.	364687.	364708.	3736[illegible]	379921.	388863.	419288.
100.	364678.	64680.	364686.	364693.	364714.	3736[illegible]	379926.	388868.	419293.
5000.	486916.	86918.	486923.	493165.	514920.	5149[illegible]	530132.	530167.	568300.
10000.	637133.	37134.	643375.	643382.	651110.	66005[illegible]	660088.	688092.	703374.
15000.	786150.	86151.	786157.	786164.	801327.	80136[illegible]	810305.	816575.	861298.
20000.	936517.	36519.	936524.	942766.	942787.	95943[illegible]	959472.	974649.	998839.
30000.	1235980.	35981.	1235987.	1235994.	1242250.	125889[illegible]	1258935.	1267877.	1298302.
35000.	1385074.	385075.	1385081.	1385088.	1394016.	139405[illegible]	1409228.	1409264.	1447396.
40000.	1522692.	1522694.	1522699.	1522706.	1528962.	153790[illegible]	1558473.	1567416.	1597841.

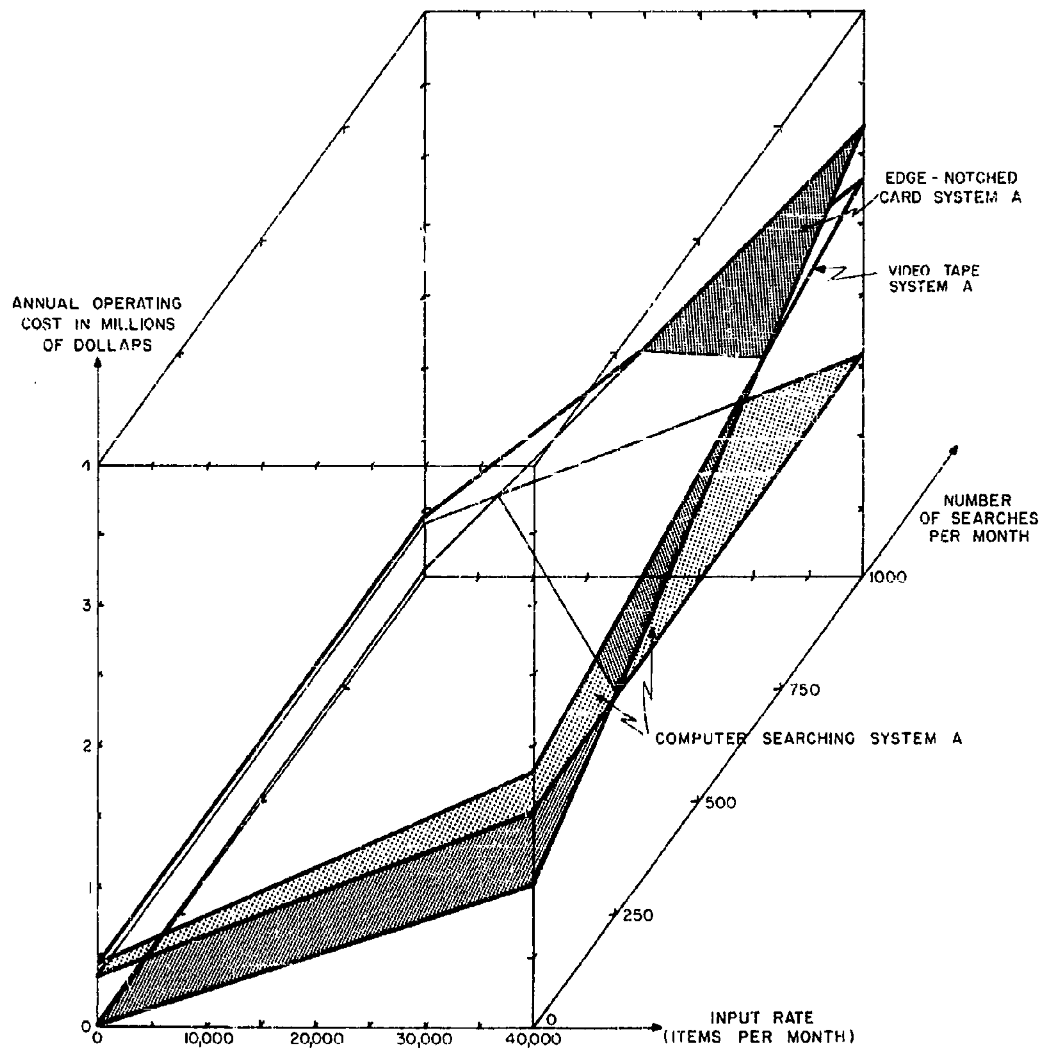
FIG. 14 COST CALCULATIONS FOR COMPUTER SYSTEM A - GENERAL CASE

COST CALCULATIONS (IN DOLLARS PER YEAR)

VIDEO TAPE SYSTEM A
INITIAL FILE SIZE .
RATE OF RETURN .070
AMORTIZATION PERIOD 5.00
BURDEN RATE .150
OVERHEAD RATE .250

INPUT RATE (ITEMS/MO.)	SEARCH VOLUME (NUMBER OF SEARCHES PER MONTH)								
	0.	10.	50.	100.	250.	500.	750.	1000.	2000.
0.	437284.	437433.	438028.	438771.	441002.	444720.	457409.	467455.	506596.
50.	437316.	437465.	438062.	438808.	441046.	453747.	457477.	476507.	515698.
100.	437347.	437497.	438095.	438844.	441090.	453803.	463874.	476588.	515829.
5000.	582200.	582399.	583194.	597077.	615327.	620294.	640560.	645527.	803618.
10000.	757456.	757705.	758699.	759943.	776299.	808411.	816680.	860676.	1135633.
15000.	930075.	930373.	931568.	933061.	951569.	968439.	1048317.	1141056.	1469642.
20000.	1105338.	1105687.	1112140.	1116989.	1124319.	1159726.	1280365.	1357038.	1803523.
30000.	1465598.	1466046.	1467840.	1470082.	1481868.	1617059.	1729579.	1866458.	2428063.
35000.	1630575.	1631073.	1633067.	1638577.	1660172.	1824384.	1968072.	2154963.	2834508.
40000.	1807602.	1808150.	1821731.	1827579.	1840924.	2035554.	2195635.	2375296.	3094218.

FIG. 15 COST CALCULATIONS FOR VIDEO TAPE SYSTEM A – GENERAL CASE



NOTE: ALL THREE SYSTEMS STARTED WITH AN INITIAL FILE SIZE OF ZERO ITEMS.

FIG. 16 ANNUAL COST OF THREE STORAGE AND RETRIEVAL SYSTEMS – GENERAL CASE

operations could be used for many of the operations of any proposed retrieval system. However, accurate, standardized times do not exist and, to our knowledge, no concerted effort is being made by any organization to develop such data. The unit times and costs used in our sample evaluations were crude estimates, and should not be used for evaluation purposes without first determining their accuracy. As discussed later in Sec. VII, more research directed toward the development of elemental times and costs for basic operations performed in documentation and information retrieval would be helpful.

2. Cash Flow and Other Computations for Specific Problems

This program was written for use in those cases when more detailed information is available to describe the future problem parameters for a given user. For example, an abstracting or indexing service that is considering the establishment of a literature-searching system would have a fairly accurate idea of what accession rate and volume of search requests it will encounter during the next few years of operation. In this type of situation, the user desires to compare the costs of candidate systems for his particular problem. That is, he wants to compare the expenditures of each candidate over some specified time, say five or ten years. This program accepts the same basic information as the general cost analysis program, and prints a total monthly operating cost for each month in a 10-year period, as illustrated in Figs. 17, 18, and 19. When plotted, this results in a graphic portrayal of the monthly expense cash flow for a particular system over a 10-year period. Figure 20 illustrates the cash flow for three candidate systems.

Given the cash flows for several alternative systems, we need some method of choosing the most attractive candidate. In cases where the curves completely overlap each other, the choice is simple. However, where the curves intersect at some time in the future, the choice is not simple, and must consider the time value of money. Two methods of comparison which are useful in such situations are the "present worth" and "equivalent annual cost." The present-worth method determines the present worth of a time sequence of expenses. That is, it determines

COST CALCULATIONS (IN DOLLARS PER YEAR)

EDGE-NOTCHED CARD SYSTEM
INITIAL FILE SIZE
RATE OF RETURN .070
AMORTIZATION PERIOD 5.00
BURDEN RATE .150
OVERHEAD RATE .250

YEAR	INPUT RATE (ITEMS/MO.)	SEARCH LOAD (SEARCHES/MO.)
1	650.	20.
2	850.	150.
3	1000.	300.
4	1150.	850.
5	1250.	1250.
6	1325.	1325.
7	1325.	1500.
8	1325.	1575.
9	1325.	1700.
10	1325.	1825.

YEAR	MONTH	COST
1	1	2003.
1	2	2003.
1	3	2003.
1	4	2003.
1	5	2003.
1	6	2003.
1	7	2003.
1	8	2003.
1	9	2003.
1	10	2003.
1	11	2003.
1	12	2003.
2	1	3747.
2	2	3747.
2	3	3747.
2	4	4256.
2	5	4256.
2	6	4256.
2	7	4256.
2	8	4256.
2	9	4256.
2	10	4764.
2	11	4764.
2	12	4764.
3	1	8969.
3	2	9477.
3	3	9477.
3	4	9985.
3	5	9985.
3	6	10494.
.	.	.
.	.	.
.	.	.

YEAR	EQUIV. ANNUAL COST	PRE[illegible]
1	26563.	23201.
2	37432.	67679.
3	59817.	167969.
4	112957.	438052.
5	177274.	890434.
6	229665.	1434940.
7	278400.	2104362.
8	318090.	2850507.
9	352085.	3683535.
10	381115.	4599227.

FIG. 17 COST CALCULATIONS FOR EDGE-NOTCHED CARD SYSTEM A – SPECIFIC PROBLEM

COST CALCULATIONS (IN DOLLARS PER YEAR)

COMPUTER SYSTEM A
INITIAL FILE SIZE .
RATE OF RETURN .070
AMORTIZATION PERIOD 5.00
BURDEN RATE .150
OVERHEAD RATE .250

YEAR	INPUT RATE (ITEMS/MO.)	SEARCH LOAD (SEARCHES/MO.)
1	650.	20.
2	850.	150.
3	1000.	300.
4	1150.	850.
5	1250.	1250.
6	1325.	1325.
7	1325.	1500.
8	1325.	1575.
9	1325.	1700.
10	1325.	1825.

YEAR	MONTH	COST
1	1	30199.
1	2	30199.
1	3	30199.
1	4	30199.
1	5	30199.
1	6	30199.
1	7	30199.
1	8	30199.
1	9	30199.
1	10	30199.
1	11	30199.
1	12	30199.
2	1	31434.
2	2	31434.
2	3	31434.
2	4	31434.
2	5	31434.
2	6	31434.
2	7	31434.
2	8	31434.
2	9	31434.
2	10	31434.
2	11	31434.
2	12	31434.
3	1	31437.
3	2	31437.
3	3	31437.
3	4	31437.
3	5	31437.
3	6	31437.
.	.	.
.	.	.
.	.	.

YEAR	EQUIV. ANNUAL COST	PRESENT WORTH
1	400448.	349767.
2	368990.	667141.
3	335298.	941524.
4	308331.	1195715.
5	283411.	1423552.
6	258720.	1616474.
7	235234.	1778076.
8	213824.	1916145.
9	194362.	2033428.
10	176534.	2130391.

FIG. 18 COST CALCULATIONS FOR COMPUTER SYSTEM A – SPECIFIC PROBLEM

VIDEO TAPE SYSTEM A
INITIAL FILE SIZE .
RATE OF RETURN .070
AMORTIZATION PERIOD 5.00
BURDEN RATE .150
OVERHEAD RATE .250

YEAR	INPUT RATE (ITEMS/MO.)	SEARCH LOAD (SEARCHES/MO.)
1	650.	20.
2	850.	150.
3	1000.	300.
4	1150.	850.
5	1250.	1250.
6	1325.	1325.
7	1325.	1500.
8	1325.	1575.
9	1325.	1700.
10	1325.	1825.

YEAR	MONTH	COST
1	1	36066.
1	2	36066.
1	3	36066.
1	4	36066.
1	5	36066.
1	6	36066.
1	7	36066.
1	8	36066.
1	9	36066.
1	10	36066.
1	11	36066.
1	12	36066.
2	1	37466.
2	2	37466.
2	3	37466.
2	4	37466.
2	5	37466.
2	6	37466.
2	7	37466.
2	8	37466.
2	9	37466.
2	10	37466.
2	11	37466.
2	12	37466.
3	1	37654.
3	2	37654.
3	3	37654.
3	4	37654.
3	5	37654.
3	6	37654.
.	.	.
.	.	.
.	.	.

YEAR	EQUIV. ANNUAL COST	PRESENT WORTH
1	478242.	417715.
2	440226.	795937.
3	400560.	1124780.
4	369774.	1433991.
5	343200.	1723870.
6	324069.	2024776.
7	323393.	2444455.
8	312863.	2803668.
9	297987.	3117557.
10	294242.	3550864.

FIG. 19 COST CALCULATIONS FOR VIDEO TAPE SYSTEM A – SPECIFIC PROBLEM

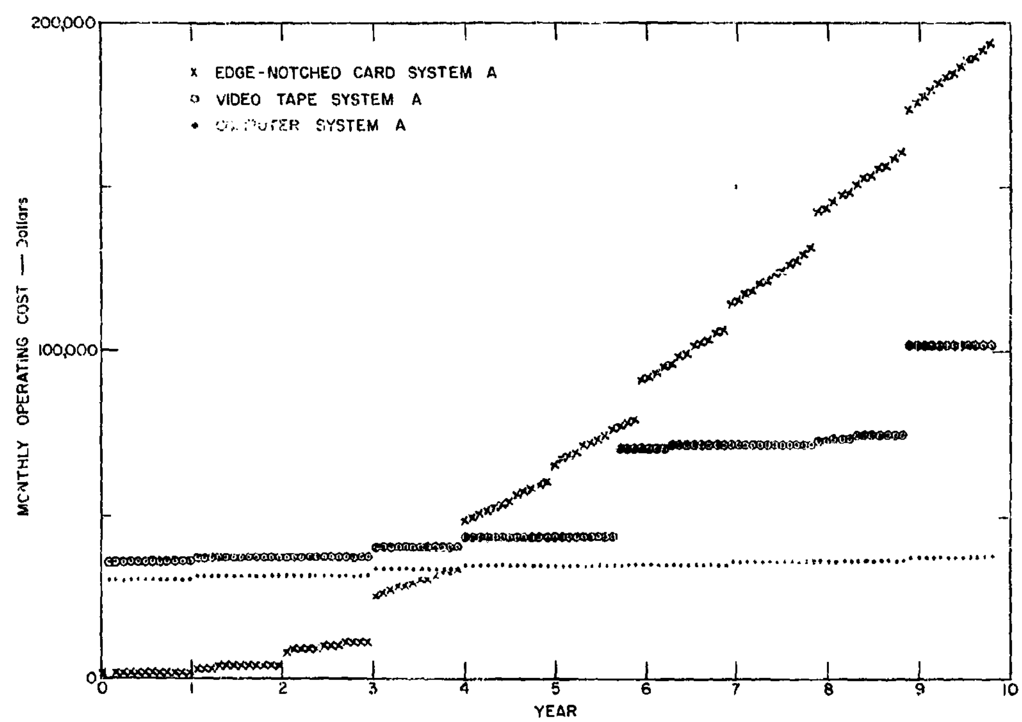


FIG. 20 MONTHLY OPERATING COSTS OF THREE STORAGE AND RETRIEVAL SYSTEMS – SPECIFIC PROBLEM

how much money would have to be put in the bank today to exactly meet the prescribed series of payments over the coming 10-year period at a given interest rate. The candidate system with the lowest present-worth figure is obviously the most attractive from an economic standpoint. The second comparison method determines an equivalent annual cost over a specified number of years.* In this way, a series of unequal monthly costs over a 10-year period could be converted to an equivalent annual cost. Obviously the system with the lowest annual cost is the most attractive from an economic standpoint. The program computes both a present worth and an equivalent annual cost for each candidate and includes this in the printout shown in Figs. 17, 18, and 19. These values are computed for 1-, 2-, 3-, . . . 10-year periods, so that systems can be directly compared for any operating period from 1 to 10 years. In the examples shown, the card, computer, and video tape systems have present worths of $890,434, $1,423,552, and $1,723,870, respectively, when figured over a 5-year operating period. Over this interval, the card system would be the most attractive choice from an economic standpoint. Over a 10-year operating period, the card, computer, and video tape systems would have present worths of $4,599,227, $2,130,391, and $3,550,864, respectively. This would indicate that over a 10-year operating period the computer system would be the most attractive choice.

In the examples shown, the cost analysis programs only considered a time series of generally unequal debits (expenses). However, the programs could also accommodate an accompanying time series of generally unequal credits (income) to arrive at a net present worth or annual cost.

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*This equivalent annual cost should not be confused with the actual annual costs. The equivalent annual cost is obtained by extending, for an N-year period, the present worth in equal annual payments, considering some specified interest rate.

E. The Utility of the Evaluation Procedures

The coarse screening procedures can be used immediately to give some indications of how the capabilities of a particular system may fit in the range of some of the variables that will be encountered by storage and retrieval systems. Since only a few variables have been studied to date, the collected information provides only a cursory screening. However, the procedure's usefulness can be improved by the collection of more data; there is no fundamental reason why this approach cannot be extended to cover more parameters.

The performance evaluation procedure that matches performance with requirement, and includes relative weightings for each requirement, could be used as an interim tool. However, it has some basic limitations, and it requires some specific information about the intended user population before it can be used. The basic objections and limitations of this procedure are: (1) to a large measure it relies upon opinions stated by users who are conditioned to their present systems, so that the procedure never really separates need from habit; (2) there are basic theoretical problems in deriving a single weighting factor for each requirement. Even if these limitations are accepted, as they probably would be for an interim application, some additional data must be collected before the procedure can be used. Specifically, statements and measurements of the requirements and their relative weightings must be obtained for the intended user population. It is possible that continued development of this procedure would provide some answers to the stated objections.

The performance evaluation procedure that uses a model to reduce each requirement to the common denominator of time or cost would seem to be a potentially useful tool. However, it will require considerably more development before it can be considered to be a useful tool. Basically, the approach seems to be very sound, and bypasses the objections stated for the first evaluation procedure.

Both of the cost analysis programs could be applied immediately if the basic operating data and descriptions were available. The approach

is basically sound, and can be improved even further with additional effort. However, to ensure fair accuracy in an actual evaluation, basic data and operating procedures would have to be applied in more detail than they currently exist.

VII PROBLEM AREAS AND SUGGESTIONS FOR FURTHER RESEARCH

This section provides some suggestions for further research for the longer-range development of more basic and exhaustive criteria and methods for the assessment of alternative systems and procedures. The research results described in this report were the results of a relatively brief study aimed at the development of rough measures of worth for candidate systems. A need still exists for the development of a longer-range research effort aimed at improving the methodology for comparison of information systems. Such research would ultimately result also in a better understanding of the role of information systems in increasing scientific productivity.

The following general areas should be considered in any future research program for evaluation procedures: (1) development of methodology for determining user requirements; (2) determination of elemental times and costs of the basic operations performed in storage and retrieval systems; (3) development and use of modelling for performance evaluation; (4) development and use of modelling for analysis of operating costs; (5) pilot tests or evaluations of representative systems; (6) additional basic studies.

A. Methodology for Determining User Requirements

Additional work should be done to develop and improve methods for determining user requirements. This has been an extremely difficult study methodologically--some problems have been attacked successfully but many others remain. The problem of classifying criteria should receive further attention. The criteria might be classified in some manner by the type of person affected (e.g., system manager, operator, or user) or by the basic conceptual units.

Further work should be done to distinguish between the needs of the user and habits conditioned by his particular environment. Intuitively, one would expect that for a given task the user's needs for information would be the same, regardless of his organizational affiliation and the facilities available to him. Thus, need should not be confused with

habit. However, it does seem to be true that the way in which the user expresses his needs is conditioned by the present facilities available to him. It might be more desirable, although perhaps more difficult, to present the user with a set of specifications designed to test and measure the importance of various criteria. The following test is an oversimplification, but it does indicate the approach:

"Which of the following would be more suitable for you:

a. A system which would provide references within 24 hours with 50 percent irrelevant references.

b. A system which would provide references within one week with virtually no irrelevant material."

The difficulty of the method is to keep the number of situations presented to the user within bounds and still test the required number of criteria.

Some attention should be given to the measurement of requirements that were not considered during the preliminary study, as well as to the refinement of some of the measurements that have already been made. Perhaps this might be coupled with a measurement of the requirements of a particular user population that is considering the installation of some comprehensive information services.

B. Determination of Elemental Times and Costs

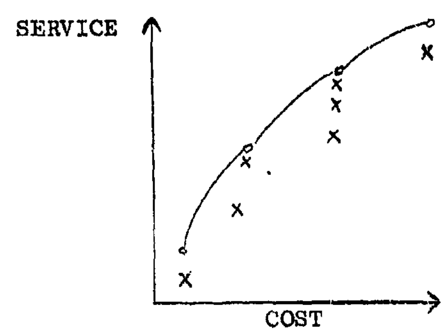
As mentioned earlier, the accuracy of the models and the cost analyses depends, in large measure, on the accuracy of the basic time and cost data. An operations-analysis study of several operating systems to develop a collection of realistic time and cost factors for the basic functional elements would be very helpful for the modelling operations.

C. Modelling for Performance Evaluation

1. General

The selection of a document retrieval system (DRS) ultimately depends on choosing a combination of cost and service that best meets stated requirements. The budget restraint is important.

Suppose it were possible to determine the cost of a DRS and measure the service it provided. Then each cost-service combination could be plotted as a point on the following graph:



Notice that for a given cost, one DRS gives the best service. The point that marks this DRS is called the efficient point, and the curve through the efficient points is called the efficient curve.

An analogy may help to clarify this idea. Before buying an automobile it is convenient to separate the available cars into classes according to cost: e.g., compacts and luxury cars. The choice of a car within a cost class would then depend only on the service provided. It may be difficult to measure certain aspects of service (e.g., what is the value of a quiet ride?), but if this could be done, then there would be a car in each cost class, the efficient car, which would give the best service.

To construct a DRS efficient curve then, it is necessary to compute service and cost data for each choice. This computation will require some experimentation and observation of the system under actual operating conditions. In the case of installed systems, this may not be difficult to do. But for proposed or prototype systems such study may be difficult and expensive. It may be sufficient to estimate some components of cost and service by observing operating systems similar to the proposed system. Other components however, will have to be derived from engineering specifications and educated guesses.

There have been suggestions on how to conduct experiments to obtain data on DRS service.[2] The chief difficulty appears to be the cost of such experimentation.

2. Service

The purpose of a DRS is to satisfy a user's request for information. In any DRS, the cost in time of providing this service is composed of four parts: (1) the time to prepare input requests, (2) the time to obtain the output documents, (3) the time to read the output documents, and (4) the time to reformulate and reprocess the request if the first search is unsuccessful, or the time needed to search elsewhere if the information is not in the file.

There are two "kinds" of time involved in DRS service. First there is the time when the user formulates requests and reads output documents, but when the DRS is free to operate on other search requests. Second there is the time when the DRS operates on the request but when the user is free to do other things. It seems clear that from the user's standpoint a minute of the first kind of time is not the same as a minute of the second kind of time, unless the user has only one job to do and cannot proceed with that job until he receives the search results. In this situation, total user time is the elapsed time from the moment the request is formulated until the information is obtained.

But if there are other things the user can do during the machine search, then his waiting time is not wasted and total user time is only the time he spends directly in the search effort. In this circumstance, there may be no significant difference in service provided by a DRS which completes a search in a minute and one that takes a week. However, there are indications that the performance of the individual drops as much as 25% on these alternative tasks when he is waiting for information.[11]

To compute total service time it is necessary to convert DRS search time to user participation time. This can only be done through knowledge of the work habits of the population using the DRS.

In summary, total service time, T, is

$$T = T_1 + \lambda T_2$$

where

T_1 = user time expended in preparing search requests and analyzing search output

T_2 = DRS search time

λ = a factor ($o \leq \lambda \leq 1$) for converting DRS search time to user time (represents the degree to which the user is idle or inefficient while the search is being conducted).

The conversion problem; i.e., setting the value of λ, involves a judgement or measurement by someone familiar with the particular library and group of users under analysis.

Total service time over some time span (e.g., one year) is the product of the average service time per search and the amount of library use. The latter statistic is usually known. The former can be estimated through detailed analysis of the functions performed between the moment a need for information is defined until this need is filled. Insofar as types of functions can be separated, the first four functions discussed below are DRS functions, the remaining three are user functions.

3. Communication of the Request

Normally a request for information is first phrased in the user's natural language. Therefore, the request must be converted into a form acceptable to the DRS and then entered onto the standard input medium, such as punched cards. The conversion can be done mechanically or by human beings. In either case, the average time to completely translate a request into a suitable input form can be estimated by direct observation.

4. File Search

Searching can be done mechanically or by human beings. The estimated search time should include all the time from the moment the coded user request is available to the time the search is completed. If the DRS batches requests before searching begins, then waiting time is a part of search time. Similarly, if the output is batched before it is distributed, then this waiting time also must be included in the total. File search time can be estimated by observing system performance on a sample of requests.

5. Document Retrieval

If the output consists of citations or document numbers, then it will be necessary to obtain the document itself or an abstract of it. For some DRS this task is incorporated in the file search; for others it will require another search and consequently more time. If the DRS does not produce the document itself, then the time required by the user to get the document will also have to be considered. Document retrieval time can be estimated from a sample of searches.

6. Document Duplication

In many systems, copies must be made of the retrieval documents. The average time for duplicating output is easily computed. If the DRS output is the document itself and not a copy (for example, if the output is a book from a library shelf), then other users who have need for the document will have to wait until it gets back into circulation. This waiting time is harder to estimate.

7. Rejection of Nonrelevant Material

It is likely that the output of a DRS search will contain irrelevant documents (false drops). The false drops must be read to determine that they are irrelevant, and this takes time; the greater the number of false drops, therefore, the greater the time wasted reading them. Reading time depends, to a great extent, on the length of the document. From this standpoint, an output consisting of titles and abstracts are preferable to full documents. But it is more likely

that a relevant document will be rejected on the basis of a title or a brief abstract than by seeing the full text. The time lost through this kind of error of omission is discussed below.

Time spent rejecting irrelevant material is directly observable. The proportion or distribution of false drops can be obtained by an experiment involving a sample of requests.

8. Omission of Relevant Material

The cost in time resulting from the system's failure to provide requested information, for whatever reason, is perhaps the most important component of total service time and the most difficult to estimate.

It is possible to determine the probability of not finding relevant material by performing an exhaustive search on a sample of search failures. Expected search time, T, then is

T = (Probability of retrieving information)·(time to retrieve the information) + (Probability of not retrieving information)·(sum of the times in the steps taken by the user to get the information).

What steps does a user take when the information he seeks is not in the output? If the user has reason to believe the information is available in the file, he can rephrase the request and search the file again. If on the other hand, he does not think the information is in the file, then he must search elsewhere, or proceed with his work without the knowledge he wants.

The time involved in resubmitting a request has been summarized above. The time to seek information elsewhere--i.e., other libraries--is also observable. But if no more searching is done, then what is the cost in time to the user? It is not probable that this time can be measured, but it can be assumed that when a DRS does not satisfy a user's first request, a time penalty is incurred. One penalty that can be used is the average time it would take to search the Library of Congress or some other comprehensive file for the information.

9. Cost

Total system cost is composed of variable and fixed components. The annual disbursements connected with a mechanized DRS would include these variable costs: salaries, power requirements, material costs, translating costs where documents are preprocessed before they are entered into the file, document enlarging and duplicating costs, etc. Some of the costs are initial (one-time) costs: DRS purchase price, building construction, and system installation, duplicating and photographic equipment, and the initial establishment of the basic collection.

In the case of a conventional library, the annual disbursements would include these things: librarian salaries, cost of acquisition, request forms, and ventilation and lighting. One-time costs include these: building, cost of initial acquisitions, shelves, filing cabinets, hand trucks, etc. Many of these types of costs are considered in a later discussion on DRS cost analysis procedures. There is a considerable body of cost analysis experience in the digital computer field that may be applicable to mechanized document retrieval systems.

Further study and modelling of some of the more basic considerations of the evaluation procedure, such as the possibility of converting all of the user requirements and system performance characteristics into a uniform basis for comparison (e.g., time or cost) would seem to be an important long-range objective.

D. Modelling for Analysis of Operating Costs

Efforts could fruitfully be employed in the further development of the programs and procedures for analyzing the operating costs of candidate systems. Additional algorithms and programming statements could be developed to make the analysis procedure more exact and more applicable to a wider range of systems.

Sample analyses of several representative systems and their possible variations over wide ranges in operating variables such as the examples given in Sec. VI would provide much useful information for organizations considering the installation of such systems. Much interesting

information (e.g., the incremental cost of incorporating abstracts instead of references in a searching system, the incremental cost to reduce the over-all response time by some specified factor, the most economical equipment configuration or complement for a given task) can be obtained by running this model. Similarly, cost analyses of a specific problem situation (see Sec. VI) where the future operating variables can be estimated may be of interest to organizations whose problem is fairly well defined.

E. Pilot Tests or Pilot Evaluations of Representative Systems

Pilot evaluations of representative retrieval systems, either operating or hypothetical, would serve the doubly useful purpose of providing a check on the evaluation techniques as well as providing useful information about the particular systems.

F. Basic Studies

There is a need for continuing basic research to determine the following:

(1) How the user's productivity is related to the type and amount of information services provided (i.e., What is the gain in user productivity from increasing incremental amounts of information?);

(2) How the search needs are related to the tasks required of the individual (i.e., What types of information or searches are required for different types of jobs?).

APPENDIX A

RANK CORRELATION METHODS APPLIED TO QUESTIONNAIRE RESULTS

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RANK CORRELATION METHODS APPLIED TO QUESTIONNAIRE RESULTS

One of the principal tasks of the project is to develop a ranking of the importance to the users of performance characteristics of storage and retrieval systems. We do this by analyzing individual rankings obtained from a sample of the user population.

We are concerned with two problems:

(1) Measuring the agreement, or concordance, among the individual rankings, and

(2) Estimating the "true" ranking of the performance characteristics.

We can answer both questions by using rank correlation methods.

The following example, based on a problem in Chapter 6 of Kendall[7] illustrates the procedure for computing the degree of concordance among the rankings and testing its significance.

Consider the three rankings of seven characteristics:

	A	B	C	D	E	F	G
P	1	4	2	3	5	7	6
Q	2	1	3	4	5	6	7
R	2	1	3	4	5.5	5.5	7
Total:	5	6	8	11	15.5	18.5	20
Deviations from the mean:	-7	-6	-4	-1	3.5	6.5	8

The mean $= \frac{84}{7} = 12$.

The sum of squared deviations about the mean is $S = 220.5$.

Is the computed value of S significant? That is, does $S = 220.5$, based on the three rankings of seven objects indicate that P, Q, and R agree among themselves?

To test the significance of some sample statistic, such as S, the observed value of S is compared with the entries in a frequency distribution of all values the sample statistic may take on. Each of the possible values in the frequency distribution has a certain probability of occurrence. If the probability that a random occurrence of the observed value of the statistic is sufficiently low (say .05) then we may conclude that the observed value is significant. In the present context, a significant value of S implies that the rankings P, Q, and R agree.

To test the significance of S, we consult a table whose entries are the probabilities of exceeding various values of S. Such a table is found in Kendall's book.[12] For three rankings of seven objects, the probability that the observed value exceeds 185.6 is .01. In other words, if 100 groups of three individuals were to rank seven objects randomly, the expected number of times that the calculated value of S exceeds 185.6 is one. Since the observed value of S = 220.5 exceeds the value for 1 percent, the concordance among P, Q, and R cannot be explained satisfactorily by chance alone.

We now ask what is the best estimate we can make of the true ranking of the objects? Our answer is to rank the objects according to the sums of ranks alloted to the characteristics. For the above example this gives the ranking: A B C D E F G.

APPENDIX B

TECHNIQUE FOR COMPUTING A MEASURE OF AGREEMENT BETWEEN A REQUIREMENT AND A SYSTEM'S PERFORMANCE FOR THAT REQUIREMENT

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TECHNIQUE FOR COMPUTING A MEASURE OF AGREEMENT BETWEEN A REQUIREMENT AND A SYSTEM'S PERFORMANCE FOR THAT REQUIREMENT

The first performance evaluation procedure requires as an intermediate step, a computation of the measure of agreement (index) between a requirement and a system's performance for that requirement. This Appendix describes the procedure for this computation, as applied to two specific requirements: (1) a requirement to minimize the time to get the major group of relevant references, and (2) a requirement to minimize the amount of irrelevant material produced. Because both indexes are derived in a similar way, only the derivation for the first requirement is presented. The method can be extended to other requirements.

Minimum Time Requirement

The average service time per search will be used to measure how well a DRS satisfies the first requirement. To compute this statistic the distributions of DRS service time and user waiting time must be compounded.

User Waiting Time

Let n_t be the number of users who will wait as long as time t for search results, and let N be the total number of users. Table B-1 shows the proportion n_t/N, of users willing to wait until time t for the relevant references. The data in Table B-1 were derived from 88 responses to Question 11c in the questionnaire. Figure B-1 is a graph of the data shown in Table B-1.

Figure B-1 suggests that the distribution of n_t/N is exponential. As applied to this problem, the exponential assumption means that, in the discrete case,

$$n_t - n_{t-1} = k(N-n_{t-1})$$

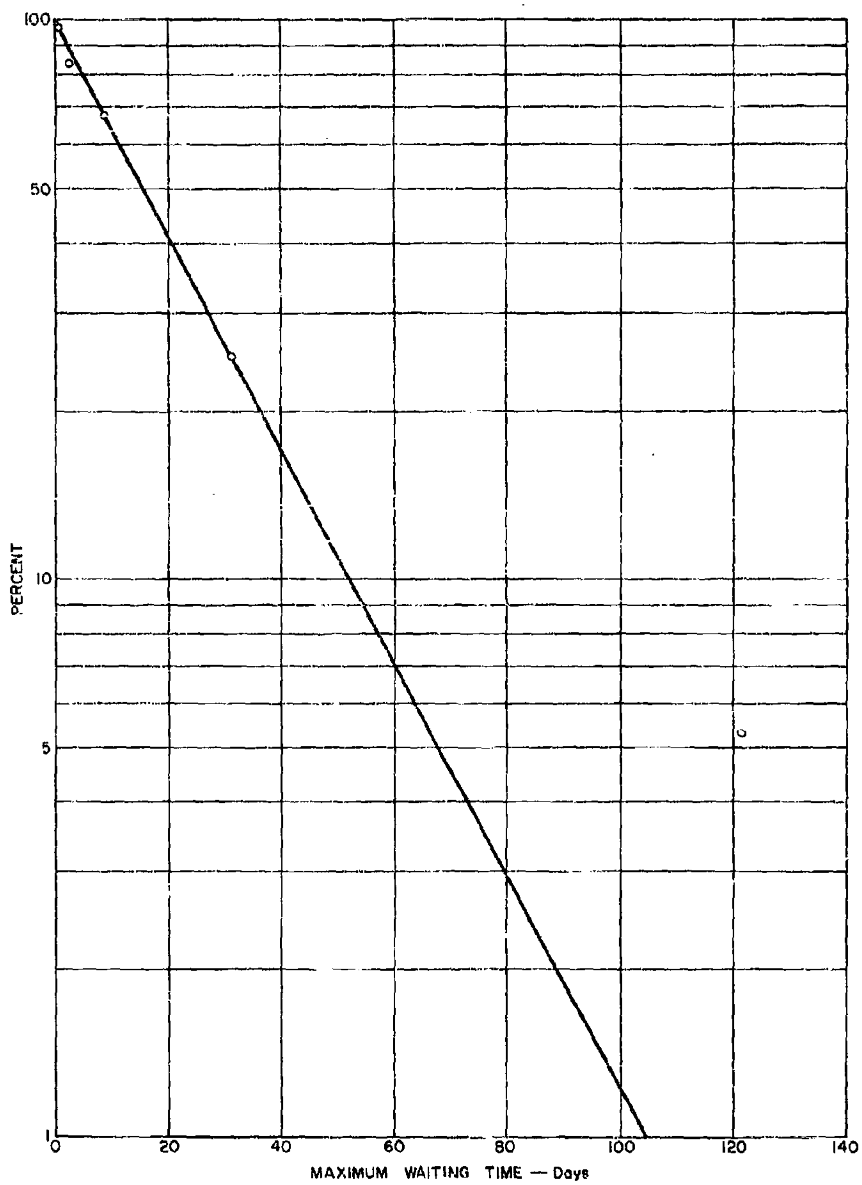

FIG. B-1 PERCENT OF RESPONDENTS WILLING TO WAIT UP TO T DAYS FOR MOST OF THE RELEVANT REFERENCES

Table B-1

PROPORTION OF USERS WILLING TO WAIT UNTIL TIME t FOR THE RELEVANT REFERENCES

Max time to get relevant references (days)	Interval mid-point (day)	$\frac{n_t}{N}$
$\leqq 1$	0.5	96.9
2-3	2.5	83.4
4-13	8.5	67.8
14-49	31.5	25.1
61-183	121.5	5.3
> 183	--	0.0

where k, the "decay constant," is the reciprocal of mean user waiting time. This difference equation says that the number of respondents in the interval from time t-1 to t is proportional to the number of respondents not satisfied before time t-1. The continuous analog of this difference equation is

$$dn_t = k(N-n_t)dt$$

or

$$\frac{1}{(N-n_t)} \frac{dn_t}{dt} = k$$

which integrated gives

$$c + \log(N-n_t) = kt$$

where c is the constant of integration. At $t = 0$, $n_t = 0$, so that $c = -\log N$. Therefore

$$\log(N-n_t) = -kt + \log N \quad .$$

Solving for n_t

$$n_t = N(1-e^{-kt}) \quad .$$

Finally

$$n_t/N = 1-e^{-kt} \quad .$$

The quotient n_t/N is the proportion of respondents who want search results by time t at the latest.

The value of k could be estimated by the least-squares fitting technique. However, the resulting value would be heavily influenced by one outlying point; the 2-6 months interval point. If this interval had been 2-3 months and the change had not affected the responses, then the exponential assumption gives a very good fit. When the outlying point is ignored, the slope of the line in Fig. B-1, k, is approximately $k = 0.02$.

DRS Service Time

No empirical data are available on DRS service time, although such data could be developed through a program of experimentation on prototype systems. In the following analysis the DRS service time distribution is denoted by g(t).

Average Service Time per Search

Figure B-2 will help explain how the average service time per search statistic is computed.

The abscissa represents user waiting time, and the distribution below the x-axis shows the proportion of users willing to wait up to the corresponding time on the x-axis. Thus, the dark area below time dt is the proportion of users willing to wait for search results till time dt.

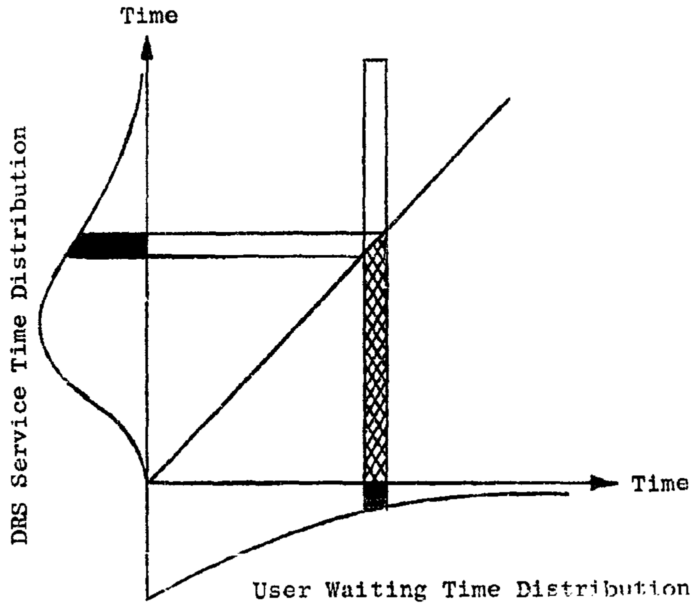

Fig. B-2

USER WAITING-TIME DISTRIBUTION

The ordinate of Fig. B-1 is also measured in units of time, in this case the amount of time required by a DRS to satisfy a search request. The distribution appended to the ordinate is the probability that a DRS will satisfy a search request by the given time. The dark area to the left of time interval dt is the probability the search is satisfied in that interval.

Consider a single user, one willing to wait up to time dt for search results. This user will generate many searches--some that can be serviced quickly, others that will take a long time to satisfy. It is assumed that the search times required to satisfy his requests are distributed uniformly over time. The column with base dt represents the searches generated by the particular user. Of these searches, only those satisfied by time dt--that is, the cross-hatched area in the column--are successful.

Let $\frac{n(t_1)}{N}$ = proportion of users willing to wait until time t_1

$g(t_2)$ = probability a search is completed by time t_2.

Then the average time per search, $\overline{T}$, is

$$\overline{T} = \int_0^\infty \frac{n(t_1)}{N} \int_0^{t_1} g(t_2)\, dt_2\, dt_1 \quad .$$

But by a previous result

$$\frac{n_t}{N} = 1-e^{-kt} \quad .$$

Therefore

$$\overline{T} = \int_0^\infty \int_0^{t_1} ke^{-kt_1} g(t_2)\, dt_2\, dt_1 \quad ,$$

or

$$\overline{T} = \int_0^\infty e^{-kt_2}\, g(t_2)\, dt_2 \quad .$$

This is as far as the analysis can be carried without knowing the form of $g(t)$.

If the DRS service-time distribution, $g(t)$ is exponential, then

$$\overline{T} = \frac{\frac{1}{k}}{\frac{1}{a} + \frac{1}{k}} \quad ,$$

where $1/a$ is the mean DRS service time, and $1/k$ is the mean user waiting time.

Note that as $1/a$ becomes large relative to $1/k$ the quotient approaches zero. Conversely when $1/a$ becomes small relative to $1/k$ the quotient approaches 1. Therefore,

$$0 < \overline{T} < 1 \quad .$$

An assumption underlying the above analysis is that user waiting time and DRS service time are independent. This may not be true. It is possible that users who are willing to wait a long time for search results are the ones whose search requests normally take a long time to satisfy. If the independence assumption is false, then $\bar{T}$ will not be an accurate measure, even though it may not be biased toward any particular DRS.

Minimum Irrelevant Material Requirement

As stated earlier, the derivation of the minimum irrelevant material index--called the average percentage of false drops per search, and signified by $\bar{D}$--is not presented. The steps followed in deriving $\bar{T}$ can be repeated to derive $\bar{D}$. The appropriate distributions in this case are the percent of users willing to accept up to d false drops, and the probability that a DRS will produce d false drops.

The result is

$$\bar{D} = \frac{\frac{1}{b}}{\frac{1}{c} + \frac{1}{b}} ,$$

when $\frac{1}{b}$ is the mean number of false drops acceptable to users and $\frac{1}{c}$ is the mean number of false drops produced by the DRS. Again $0 < \bar{D} < 1$.

APPENDIX C

GENERAL COST ANALYSIS PROGRAM WITH SPECIFIC DATA INSERTED FOR THE ANALYSIS OF COMPUTER SYSTEM A

GENERAL COST ANALYSIS PROGRAM WITH SPECIFIC DATA INSERTED

FOR THE ANALYSIS OF COMPUTER SYSTEM A

```
    BURROUGHS ALGEBRAIC COMPILER - STANDARD VERSION   7/25/61$
     INTEGER I,J,K,M,N,T$
INITIALCONDITIONS..
     N=10$ ARRAY INPUTRATE(10)=(0,50,100,5000,10000,15000,20000,30000,
                35000,40000)$
     M=9 $ ARRAY SEARCHLOAD(9)=(0,10,50,100,250,500,750,1000,2000)$
     FILESIZE=0$
     ROFR=0.07 $ COMMENT THIS IS RATE OF RETURN$
     YEARS=5.0 $ COMMENT EQUIPMENT AMORTIZATION PERIOD$
     BURDEN=0.15$
     OVERHEAD=0.25$
CONSTANTS..
    ARRAY  ANSWER(11),D(100,4),C(100),R(100)$
     MINS=10200.0$
     HOURS=170.0$
     FORMAT HEADER1 (B40,*COST CALCULATIONS (IN DOLLARS PER YEAR)*,W3),
            HEADER2 (
*COMPUTER SYSTEM A *
                 ,W4),
            HEADER3 (*INITIAL FILE SIZE*,S10.0,W0,
                     *RATE OF RETURN*,S5.3,W0,
                     *AMORTIZATION PERIOD*,S5.3,W0,
                     *BURDEN RATE*,S5.3,W0,
                     *OVERHEAD RATE*,S5.3,W0),
            HEADER4 (*INPUT RATE*,B20,*SEARCH VOLUME (NUMBER OF SEARCH*
                   *ES PER MONTH)*,W4),
            HEADER5 (*(ITEMS/MO.)*,W2),
            HEADER6 (B10,11X10.0,W2),
            COSTFORMAT (X8.0,B2,11X10.0,W0)$
     OUTPUT HEADERLINE3 (FILESIZE,ROFR,YEARS,BURDEN,OVERHEAD),
            HEADERLINE6 (FOR J=(1,1,M) $SEARCHLOAD(J)),
            COSTLINE (INPUTRATE(I),FOR J=(1,1,M) $ANSWER(J))$
PARAMETERS..
     R(1)=1000$    D(1,3)=0$
     R(2)=720$     D(2,3)=20$
     R(3)=500$     D(3,1)=21.5$   D(3,2)=20$
     R(4)=350$     D(4,1)=1$      D(4,2)=5$
     R(5)=350$     D(5,1)=12$     D(5,2)=16$
     R(6)=750$                                   D(6,3)=3$
     R(7)=250$                                   D(7,3)=1$
     R(25)=6000$   D(25,1)=6$     D(25,2)=8$
     R(26)=1000000$D(26,1)=0.0075$D(26,2)=0.05$ D(26,3)=0.05/20000.0$
     R(61)=0.00014$ D(61,1)=6.1$   D(61,2)=8.1$
     R(62)-75$                                   D(62,3)=1.0/200000.0$
     R(81)=2000$    D(81,1)=0.0075$D(81,2)=0.05$ D(81,3)=0.05/20000.0$
                    D(81,4)=1000$
START..
     WRITE ($$HEADER1)$
     WRITE ($$HEADER2)$
     WRITE ($$HEADERLINE3,HEADER3)$
     WRITE ($$HEADER4)$
     WRITE ($$HEADER5)$
     WRITE ($$HEADERLINE6,HEADER6)$
     IF M GTR 11 $  M=11$
```

```
     MINT=ROFR/12$COMMENT THIS IS MONTHLY EQUIV. NOMINAL INTEREST$
COMMENT COMPUTE CHARGES$
     CHARGES=1+BURDEN+OVERHEAD+BURDEN.OVERHEAD$
     AMORT=(MINT(1+MINT)*(YEARS.12))/((1+MINT)*(YEARS.12)-1)$
ITEM..  FOR I=(1,1,N)$ BEGIN
                ITEMS=INPUTRATE(I)$
                FOR K=(1,1,11)$ ANSWER(K)=0$
SEARCH..FOR J=(1,1,M) $ BEGIN
                SIZE=FILESIZE$
                SEARCHES=SEARCHLOAD(J)$
TIME..  FOR T=(11,-1,0)$ BEGIN
                FOR K=(1,1,50)$ C(K)=0$
                TOT1=TOT2=TOT3=TOT4=0$
COMMENT COMPUTE LABOR TYPE A COST$
     IF  R(1) NEQ 0$  BEGIN
         EITHER IF ENTIRE ((D(3,1).ITEMS+D(3,2).SEARCHES)/MINS+1)
             +ENTIRE ((D(4,1).ITEMS+D(4,2).SEARCHES)/MINS+1)
               +ENTIRE ((D(5,1).ITEMS+D(5,2).SEARCHES)/MINS+1)
           GTR D(1,3)$ C(1)=C(1)+R(1)$OTHERWISE$C(1)=0$
                          END$
COMMENT COMPUTE LABOR TYPE B COST$
     IF (R(2) NEQ 0) AND (D(2,3) NEQ 0)$ BEGIN
           C(2)=C(2)+R(2)(ENTIRE ((
              ENTIRE ((D(3,1).ITEMS+D(3,2).SEARCHES)/MINS+1)
             +ENTIRE ((D(4,1).ITEMS+D(4,2).SEARCHES)/MINS+1)
             +ENTIRE ((D(5,1).ITEMS+D(5,2).SEARCHES)/MINS+1)
                         )/D(2,3))
                         )
                          END$
COMMENT COMPUTE LABOR TYPE C COST$
     IF R(3) NEQ 0 $
           C(3)=R(3)(ENTIRE (D(3,1).ITEMS/MINS
               +D(3,2).SEARCHES/MINS+1))$
COMMENT COMPUTE LABOR TYPE D COST$
     IF R(4) NEQ 0 $
           C(4)=R(4)(ENTIRE (D(4,1).ITEMS/MINS
               +D(4,2).SEARCHES/MINS+1
               +D(4,3).SIZE/HOURS
               +D(4,1).SEARCHES.SIZE.D(63,3)/MINS
                         ))$
COMMENT COMPUTE LABOR TYPE E COSTS$
     IF R(5) NEQ 0 $
           C(5)=R(5)(ENTIRE (D(5,1).ITEMS/MINS
               +D(5,2).SEARCHES/MINS+1))$
COMMENT COMPUTE LABOR TYPE F COST$
     IF R(6) NEQ 0 $
           C(6)=R(6).D(6,3)$
COMMENT COMPUTE LABOR TYPE G COST$
     IF R(7) NEQ 0 $
           C(7)=R(7).D(7,3)$
COMMENT COMPUTE EQUIPMENT TYPE A COST$
     IF R(21) NEQ 0 $
           C(21)=R(21)(ENTIRE (D(21,3).SIZE+1))$
COMMENT COMPUTE EQUIPMENT TYPE B COST$
```

```
     IF R(22) NEQ 0 $
          FOR K=(1,1,20)$
               IF C(K) NEQ 0 $ C(22)=C(22)+R(22).D(22,3).(C(K)/R(K))$
COMMENT COMPUTE EQUIPMENT TYPE C COSTS
     IF R(23) NEQ 0 $
               IF C(4) NEQ 0 $ C(23)=R(23).D(23,3).(ENTIRE (D(4,1).
                    ITEMS/MINS+D(4,2).SEARCHES/MINS+1))$
COMMENT COMPUTE EQUIPMENT TYPE D COSTS
     IF (R(25) NEQ 0) AND (D(25,4) EQL 0)$
          C(25)=R(25)(ENTIRE(D(25,1).ITEMS/(2.MINS)
               +D(25,2).SEARCHES/(2.MINS)+1))$
     IF (R(25) NEQ 0) AND (D(25,4) NEQ 0)$BEGIN
          TEMP=ENTIRE(D(25,1).ITEMS/MINS+D(25,2).SEARCHES/MINS+1)$
          C(25)=R(25)(ENTIRE ((TEMP+1)/2))+D(25,4)(ENTIRE (TEMP/2))$
                      END$
COMMENT COMPUTE EQUIPMENT TYPE E COSTS
     IF (R(26) NEQ 0) AND (D(26,4) EQL 0)$
          C(26)=R(26)(ENTIRE (D(26,1).ITEMS/(2.MINS)
                +D(26,2).SEARCHES/(2.MINS)
                +D(26,3).SIZE.SEARCHES/(2.MINS)+1))$
     IF (R(26) NEQ 0) AND (D(26,4) NEQ 0)$BEGIN
          TEMP=ENTIRE (D(26,1).ITEMS/MINS+D(26,2).SEARCHES/MINS
                +D(26,3).SIZE.SEARCHES/MINS+1)$
          C(26)=R(26)(ENTIRE ((TEMP+1)/2))+D(26,4)(ENTIRE (TEMP/2))$
                      END$
COMMENT COMPUTE MATERIAL TYPE A COSTS
     IF R(61) NEQ 0$
          C(61)=R(61)(        D(61,1).ITEMS+D(61,2).SEARCHES   ) $
COMMENT COMPUTE MATERIAL TYPE B COSTS
     IF R(62) NEQ 0$
          C(62)=R(62)(ENTIRE(D(62,3).SIZE+10))$
COMMENT COMPUTE MATERIAL TYPE C COSTS
     IF R(63) NEQ 0$
          C(63)=R(63)(SEARCHES.SIZE.D(63,2).D(63,3))$
COMMENT COMPUTE MISC. TYPE A COSTS
     IF (R(81) NEQ 0) AND (D(81,4) EQL 0)$
          C(81)=R(81)(ENTIRE (D(81,1).ITEMS/(2.MINS)
                +D(81,2).SEARCHES/(2.MINS)
                +D(81,3).SIZE.SEARCHES/(2.MINS)+1))$
     IF (R(81) NEQ 0) AND (D(81,4) NEQ 0)$BEGIN
          TEMP=ENTIRE (D(81,1).ITEMS/MINS+D(81,2).SEARCHES/MINS
               +D(81,3).SIZE.SEARCHES/MINS+1)$
          C(81)=R(81)(ENTIRE ((TEMP+1)/2))+D(81,4)(ENTIRE (TEMP/2))$
                      END$
COMMENT COMPUTE TOTAL LABOR COST$
          FOR K=(1,1,20)$
               TOT1=TOT1+C(K)$
               TOT1=TOT1.CHARGES$
COMMENT COMPUTE TOTAL EQUIPMENT COST$
     IF AMORT NEQ 0$ BEGIN
          FOR K=(21,1,60)$
               TOT2=TOT2+C(K)$
               TOT2=TOT2.AMORT$
                      END$
```

```
 COMMENT COMPUTE TOTAL COSTS
           FOR K=(61,1,100)$
                TOT3=TOT3+C(K)$
      ANSWER(J)=ANSWER(J)+(TOT1+TOT2+TOT3)(1+MINT)*T$
           SIZE=SIZE+ITEMS$
                      END$
                      END$
      WRITE ($$COSTLINE,COSTFORMAT)$
                      END$
      FINISH$
COMPILED PROGRAM ENDS AT 1183
PROGRAM VARIABLES BEGIN AT 3725
```

APPENDIX D

COST ANALYSIS PROGRAM FOR CASH-FLOW AND PRESENT-WORTH COMPUTATIONS WITH DATA INSERTED FOR THE ANALYSIS OF EDGE-NOTCHED CARD SYSTEM A

COST ANALYSIS PROGRAM FOR CASH FLOW AND PRESENT WORTH COMPUTATIONS WITH DATA INSERTED FOR THE ANALYSIS OF EDGE-NOTCHED CARD SYSTEM A

```
    BURROUGHS ALGEBRAIC COMPILER - STANDARD VERSION   7/25/61$
     INTEGER I,J,K,M,N,T$
INITIALCONDITIONS..
     N=10$ ARRAY INPUTRATE(10)=(650,850,1000,1150,1250,1325,1325,
            1325,1325,1325)$
     M=10$ ARRAY SEARCHLOAD(10)=(20,150,300,850,1250,1325,1500,
            1575,1700,1825)$
     FILESIZE=0$
     ROFR=0.07 $ COMMENT THIS IS RATE OF RETURN$
     YEARS=5.0 $ COMMENT EQUIPMENT AMORTIZATION PERIOD$
     BURDEN=0.15$
     OVERHEAD=0.25$
CONSTANTS..
    ARRAY  ANSWER(11),D(100,4),C(100),R(100)$
     MINS=10200.0$
     HOURS=170.0$
     FORMAT HEADER1 (B40,*COST CALCULATIONS (IN DOLLARS PER YEAR)*,W3),
            HEADER2 (
*EDGE-NOTCHED CARD SYSTEM*
                  ,W4),
            HEADER3 (*INITIAL FILE SIZE*,S10.0,W0,
                     *RATE OF RETURN*,S5.3,W0,
                     *AMORTIZATION PERIOD*,S5.3,W0,
                     *BURDEN RATE*,S5.3,W0,
                     *OVERHEAD RATE*,S5.3,W0),
           HEADER4 (*YEAR  INPUT RATE  SEARCH LOAD*,W4),
           HEADER41 (B5,*(ITEMS/MO.) (SEARCHES/MO.)*,W2),
           HEADER5 (N(B1,I2,B3,X10.0,B3,X10.0,W0)),
           HEADER6 (*YEAR  MONTH     COST*,W2),
           HEADER7 (*YEAR  EQUIV. ANNUAL COST  PRESENT WORTH*,W3),
     TOTALFORMAT (B1,I2.0,B4,I2.0,B2,X10.0,C0),
           COSTFORMAT (B1,I2.0,B6,X10.0,B6,X10.0,W0)$
     OUTPUT HEADERLINE3 (FILESIZE,ROFR,YEARS,BURDEN,OVERHEAD),
           HEADERLINE5(FOR I=(1,1,N)$( I,  INPUTRATE(I),SEARCHLOAD(I)
               )),
           COSTLINE (I,AC,PW),
           TOTALLINE (I,12-T,TOTAL)$
PARAMETERS..
     R(1)=1000$    D(1,3)=5$
     R(2)=720$     D(2,3)=20$
     R(3)=500$     D(3,1)=21.5$   D(3,2)=35.25$
     R(4)=350$     D(4,1)=7.25$   D(4,2)=16.5$   D(4,3)=1.1/30000$
     R(21)=100$    D(21,3)=1.0/60000.0$
     R(22)=260$    D(22,3)=1$
     R(23)=120$    D(23,3)=1$
     R(25)=1500$   D(25,1)=1.0/20000.0$
     R(61)=0.02$   D(61,1)=1.01$
     R(63)=0.02$                                 D(63,3)=1.01/500.0$
START..
     WRITE ($$HEADER1)$
     WRITE ($$HEADER2)$
     WRITE ($$HEADERLINE3,HEADER3)$
     WRITE ($$HEADER4)$
     WRITE ($$HEADER41)$
```

```
     WRITE ($$HEADERLINE5,HEADER5)$
     WRITE ($$HEADER6)$
     IF M GTR 11 $  M=11$
     MINT=ROFR/12$COMMENT THIS IS MONTHLY EQUIV. NOMINAL INTEREST$
COMMENT COMPUTE CHARGES$
     CHARGES=1+BURDEN+OVERHEAD+BURDEN.OVERHEAD$
     AMORT=(MINT(1+MINT)*(YEARS.12))/((1+MINT)*(YEARS.12)-1)$
ITEM..  FOR I=(1,1,N)$ BEGIN
                ITEMS=INPUTRATE(I)$
                   SEARCHES=SEARCHLOAD(I)$
TIME..  FOR T=(11,-1,0)$ BEGIN
                FOR K=(1,1,50)$ C(K)=0$
                TOT1=TOT2=TOT3=TOT4=0$
COMMENT COMPUTE LABOR TYPE A COST$
     IF  R(1) NEQ 0$  BEGIN
        EITHER IF ENTIRE ((D(3,1).ITEMS+D(3,2).SEARCHES)/MINS+1)
            +ENTIRE ((D(4,1).ITEMS+D(4,2).SEARCHES)/MINS+1)
              +ENTIRE ((D(5,1).ITEMS+D(5,2).SEARCHES)/MINS+1)
          GTR D(1,3)$ C(1)=C(1)+R(1)$OTHERWISE$C(1)=0$
                     END$
COMMENT COMPUTE LABOR TYPE B COST$
     IF (R(2) NEQ 0) AND (D(2,3) NEQ 0)$ BEGIN
          C(2)=C(2)+R(2)(ENTIRE ((
             ENTIRE ((D(3,1).ITEMS+D(3,2).SEARCHES)/MINS+1)
            +ENTIRE ((D(4,1).ITEMS+D(4,2).SEARCHES)/MINS+1)
            +ENTIRE ((D(5,1).ITEMS+D(5,2).SEARCHES)/MINS+1)
                    )/D(2,3))
                    )
                     END$
COMMENT COMPUTE LABOR TYPE C COST$
     IF R(3) NEQ 0 $
          C(3)=R(3)(ENTIRE (D(3,1).ITEMS/MINS
              +D(3,2).SEARCHES/MINS+1))$
COMMENT COMPUTE LABOR TYPE D COST$
     IF R(4) NEQ 0 $
          C(4)=R(4)(ENTIRE (D(4,1).ITEMS/MINS
              +D(4,2).SEARCHES/MINS+1
              +D(4,3).SIZE/HOURS
              +D(4,1).SEARCHES.SIZE.D(63,3)/MINS
                    ))$
COMMENT COMPUTE LABOR TYPE E COSTS$
     IF R(5) NEQ 0 $
          C(5)=R(5)(ENTIRE (D(5,1).ITEMS/MINS
              +D(5,2).SEARCHES/MINS+1))$
COMMENT COMPUTE LABOR TYPE F COST$
     IF R(6) NEQ 0 $
          C(6)=R(6).D(6,3)$
COMMENT COMPUTE LABOR TYPE G COST$
     IF R(7) NEQ 0 $
          C(7)=R(7).D(7,3)$
COMMENT COMPUTE EQUIPMENT TYPE A COST$
     IF R(21) NEQ 0 $
          C(21)=R(21)(ENTIRE (D(21,3).SIZE+1))$
COMMENT COMPUTE EQUIPMENT TYPE B COST$
```

```
     IF R(22) NEQ 0 $
          FOR K=(1,1,20)$
               IF C(K) NEQ 0 $ C(22)=C(22)+R(22).D(22,3).(C(K)/R(K))$
COMMENT COMPUTE EQUIPMENT TYPE C COST$
     IF R(23) NEQ 0 $
               IF C(4) NEQ 0 $ C(23)=R(23).D(23,3).(ENTIRE (D(4,1).
                    ITEMS/MINS+D(4,2).SEARCHES/MINS+1))$
COMMENT COMPUTE EQUIPMENT TYPE D COST$
     IF (R(25) NEQ 0) AND (D(25,4) EQL 0)$
          C(25)=R(25)(ENTIRE(D(25,1).ITEMS/(2.MINS)
               +D(25,2).SEARCHES/(2.MINS)+1))$
     IF (R(25) NEQ 0) AND (D(25,4) NEQ 0)$BEGIN
          TEMP=ENTIRE(D(25,1).ITEMS/MINS+D(25,2).SEARCHES/MINS+1)$
          C(25)=R(25)(ENTIRE ((TEMP+1)/2))+D(25,4)(ENTIRE (TEMP/2))$
                    END$
COMMENT COMPUTE EQUIPMENT TYPE E COST$
     IF (R(26) NEQ 0) AND (D(26,4) EQL 0)$
          C(26)=R(26)(ENTIRE (D(26,1).ITEMS/(2.MINS)
                +D(26,2).SEARCHES/(2.MINS)
                +D(26,3).SIZE.SEARCHES/(2.MINS)+1))$
     IF (R(26) NEQ 0) AND (D(26,4) NEQ 0)$BEGIN
          TEMP=ENTIRE (D(26,1).ITEMS/MINS+D(26,2).SEARCHES/MINS
               +D(26,3).SIZE.SEARCHES/MINS+1)$
          C(26)=R(26)(ENTIRE ((TEMP+1)/2))+D(26,4)(ENTIRE (TEMP/2))$
                    END$
COMMENT COMPUTE MATERIAL TYPE A COST$
     IF R(61) NEQ 0$
          C(61)=R(61)(        D(61,1).ITEMS+D(61,2).SEARCHES   ) $
COMMENT COMPUTE MATERIAL TYPE B COST$
     IF R(62) NEQ 0$
          C(62)=R(62)(ENTIRE(D(62,3).SIZE+10))$
COMMENT COMPUTE MATERIAL TYPE C COST$
     IF R(63) NEQ 0$
          C(63)=R(63)(SEARCHES.SIZE.D(63,2).D(63,3))$
COMMENT COMPUTE MISC. TYPE A COST$
     IF (R(81) NEQ 0) AND (D(81,4) EQL 0)$
          C(81)=R(81)(ENTIRE (D(81,1).ITEMS/(2.MINS)
                +D(81,2).SEARCHES/(2.MINS)
                +D(81,3).SIZE.SEARCHES/(2.MINS)+1))$
     IF (R(81) NEQ 0) AND (D(81,4) NEQ 0)$BEGIN
          TEMP=ENTIRE (D(81,1).ITEMS/MINS+D(81,2).SEARCHES/MINS
               +D(81,3).SIZE.SEARCHES/MINS+1)$
          C(81)=R(81)(ENTIRE ((TEMP+1)/2))+D(81,4)(ENTIRE (TEMP/2))$
                    END$
COMMENT COMPUTE TOTAL LABOR COST$
          FOR K=(1,1,20)$
               TOT1=TOT1+C(K)$
               TOT1=TOT1.CHARGES$
COMMENT COMPUTE TOTAL EQUIPMENT COST$
     IF AMORT NEQ 0$ BEGIN
          FOR K=(21,1,60)$
               TOT2=TOT2+C(K)$
               TOT2=TOT2.AMORT$
                    END$
```

```
 COMMENT COMPUTE TOTAL COSTS$
           FOR K=(61,1,100)$
                TOT3=TOT3+C(K)$
      TOTAL=TOT1+TOT2+TOT3$
       WRITE ($$TOTALLINE,TOTALFORMAT)$
      ANSWER(I)=ANSWER(I)+(TOT1+TOT2+TOT3)(1+MINT)*I$
           SIZE=SIZE+ITEMS$
                      END$
                      END$
       WRITE ($$HEADER7)$
      FOR I=(1,1,N)$
         BEGIN
           PW=0$
           FOR K=(I,-1,1)$
             PW=PW+ANSWER(K)$
           PW=PW.(1/(1+ROFR)*I)$
           AC=PW.((ROFR(1+ROFR)*2)/((1+ROFR)*I-1))$
      WRITE ($$COSTLINE,COSTFORMAT)$
                      END$
      FINISH$
COMPILED PROGRAM ENDS AT 1251
PROGRAM VARIABLES BEGIN AT 3726
```

APPENDIX E

ACCUMULATED FILE SIZES AND CURRENT ACCESSION RATES OF THE PUBLICATIONS OF SEVERAL ABSTRACTING AND INDEXING SERVICES

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ACCUMULATED FILE SIZES AND CURRENT ACCESSION RATES OF THE PUBLICATIONS OF SEVERAL ABSTRACTING AND INDEXING SERVICES

Indexing or Abstracting Service	Total Number of Citations or Abstracts published in this Service from its Beginning through 1960	Current annual publication rate
Abstract Bulletin of the Inst. of Paper Chemistry	78,500	8,500
Acoustical Society of America J.: References Section	20,000	2,650
Analytical Abstracts (British)	29,796	5,359
Applied Mechanics Reviews	53,267	7,200
ASTIA (Armed Services Technical Information Agency)	250,000	35,000
Battelle Technical Review	145,295	12,000
Bibliography of Agriculture	1,512,737	97,200
Biological Abstracts	992,032	100,000
Chemical Abstracts	2,541,023	145,200
Cobalt: Review of Technical Literature Section	1,673	500
Current Abstracts from Gen. Foods Corp. Research Center	35,000	3,000
Dissertation Abstracts	40,333	7,500
Electronic Technology (reprinted in Proc. IRE, Abstracts & Ref. Section)	57,208	4,500
Engineering Index	--	--
Forestry Abstracts (British)	72,331	5,200
Geoscience Abstracts	6,800	3,600

Index Medicus	1,075,039	140,000
IRE-PGEC Computer Abstracts	1,140	3,600
Mathematical Reviews	127,000	13,500
Meteorological and Astrogeophysical Abstracts	59,700	10,000
Nuclear Science Abstracts	115,000	31,000
Prevention of Deterioration Abstracts	19,350	1,700
Psychological Abstracts	212,855	8,500
Review of Metal Literature	145,682	14,000
Science Abstracts (British)	441,719	30,000
Semiconductor Products	6,000	1,500
Solar Energy	500	100
Technical Translations	21,917	12,000
Tobacco Abstracts	8,527	2,300
U.S. Government Research Reports	53,292	24,000

APPENDIX F

INTERVIEW GUIDE USED IN THIS STUDY AND SUMMARY OF RESPONSES

APPENDIX F

INTERVIEW GUIDE USED IN THIS STUDY AND SUMMARY OF RESPONSES

INTERVIEW GUIDE

We are conducting a study, under NSF sponsorship, to develop methods for evaluating the performance of document retrieval systems. To do this, we have to know the needs of users of documents. So we are talking to some researchers in electronics in various companies about their own document needs.

Let me give you definitions for two terms I'll be using throughout this interview. (HAND RESPONDENT CARD A AND LET HIM READ WITH YOU.)

> First, I am concerned with <u>document retrieval</u> - that is, the retrieval of entire documents, abstracts, or citations of documents. I am <u>not</u> concerned with <u>information retrieval</u> - that is, general information in response to a request, nor with <u>data retrieval</u> - that is, the retrieval of specific facts.
>
> Second, is the term <u>search</u>. This is when you, or someone else at your request, looks for references and/or documents on a given subject. A search can be extensive and made through one or more libraries, or it can be very brief - such as looking through sources you keep in your own office. <u>Not</u> included are requests for specific documents (whose complete citation is known) that you know deal with the subject. For example, you are <u>not</u> searching when you ask the library to send you a specific issue of the IRE Proceedings.

(TAKE BACK CARD A)

1. Keeping this definition in mind, have you, or anyone requested by you, conducted any searches in the last year?

______ Yes ______ No (IF NO, TERMINATE INTERVIEW)

(IF YES, ASK:)

2. Roughly, how many? ____________

1-2	24%
3-5	24
6-10	26
11 or More	23
Number not specified	3
Total	100%
Base	(92)

3a. Here is a list of some activities EE's work in (HAND RESPONDENT CARD B). In what one activity do you spend the most working time?

3b. Which activities account for the majority of your searches? (IF RESPONDENT GIVES MORE THAN THREE, ASK FOR THREE THAT ACCOUNT FOR THE MOST SEARCHES.)

3c. Now I'd like to ask you about the most recent search you did or had someone else do while engaged in one of the activities you named. Which of the activities you named required this search?

		Q. 3a One Activity Most Working Time	Q. 3b Three Activities Majority of Searches	Q. 3c One Activity Most Recent Search
a.	General project planning	12 %	15 %	3 %
b.	Theoretical design of experiments	9	21	4
c.	Design of equipment, systems, and procedures	48	58	30
d.	Conduct of lab experiments or field tests	10	14	3
e.	Correlation of experimental results with theory, or vice versa	13	22	3
f.	Review & evaluation of a specific project or product (a critique)	7	9	3
g.	Technical report writing	5	12	3
h.	Technical proposal writing	1	12	6
i.	Preparation of lectures or technical papers	2	14	12
j.	Keeping current with technical advances	1	33	11

k.	Search for novel technical ideas on which to base new projects or new research	8	27	20
l.	Serving as a consultant	4	7	1
	Other	1	3	1
	Total Base	121 % (92)	249 % (92)	101 % (92)

(TAKE BACK CARD B)

4. Do you recall some of the details of this search?

101% Yes ___—___ No (IF NO, SKIP TO Q. 20) Total 100% Base (92)

5a. Do you recall anything happening during the search that made it an easier or better search, or that made the search difficult? For example, what was the most difficult or irritating thing that happened? (PROBE)

See Table I

5b. What was the easiest or most gratifying thing that happened? (PROBE)

See Table I

5c. If a young engineer who had just joined the staff were starting this same search today, what advice would you give him to make the search easier? (PROBE)

See Table II

5d. What would you warn him about? (PROBE)

See Table II

6. Who conducted the search - you, a co-worker, a librarian, or someone else?

______	Self	80 %
______	Co-worker	12
______	Librarian	27
______	Other	2
______	Computer	9

Total 130 %
Base (92)

7. Do you recall the exact nature of your request--that is, did you just generally describe the subject, were certain terms used, or what?

See Table F-1

8. Through what library or other offices was the search conducted?

______	Company library	91 %
______	ASTIA	25
______	University or college	32
______	Other	17

Total 165 %
Base (92)

9. Which of these statements most nearly describes how urgently you needed the search results when you requested the search? Ignore the importance of the results when you received them - we'll get to that next. (HAND RESPONDENT CARD C)

14 % Very urgent; other work held up. E.g., a search for information on the characteristics of a substance to be used in a current experiment.

78 Important; needed to help determine course of future work or to help fill in gaps in your knowledge. E.g., a search for information on the performance of one of a class of possible circuits to be used in a piece of equipment.

8 Not very important; completeness of search results had little priority. E.g., a bibliography to be used as supplementary information.

Total 100 %
Base (92)

(TAKE BACK CARD C)

10. Sometimes a search turns up significant information and sometimes it adds little to the searcher's knowledge. Which of these statements most nearly describes how important the results were? (HAND RESPONDENT CARD D)

34 % Very important. E.g., changed the course of a project, provided key information needed to obtain a contract.

54 Not very important. E.g., results were used as supplementary or back-up material.

12 Unimportant. E.g., results had little or no effect on course of work.

Total 100%
Base (92)

(TAKE BACK CARD D)

11a. Approximately how long was it from the time you made your request until you had received the major group of relevant references?

11b. Was this adequate or did you really need the material sooner? (IF NEEDED SOONER, ASK HOW SOON)

11c. What was the maximum amount of time you could have waited for the major group of relevant references?

	Q. 11a Actual	Q. 11b Adequate	Q. 11c Maximum
1 day or less	29%	32%	3%
2 - 3 days	18	18	13
4 - 13 days	22	22	15
2 - 7 weeks	20	21	41
2 - 6 months	8	4	19
More than 6 months	-	-	5
No Answer	3	3	4
Total	100%	100%	100%
Base	(92)	(92)	(92)

12a. How old were the most recent references turned up by the search? In other words, how recent was the material covered by the search?

12b. Was this adequate or did you really need more recent material? (IF NEEDED MORE RECENT MATERIAL, ASK HOW RECENT.)

12c. Could you have gotten by with references that were all __________ (6 months or older, 1 year or older, etc.)? (START WITH CATEGORY AFTER "ADEQUATE" AND CONTINUE UNTIL RESPONDENT SAYS "NO.")

	Q. 12a Actual	Q. 12b Adequate	Q. 12c Gotten by? Yes	Q. 12c Gotten by? No
Under 3 months	32%	37%		—
3 - 5 months	12	15		16%
6 - 11 months	18	16		10
1 - 2 years	21	20		18
Over 2 years	10	5		22
Over 10 years	5	4	5	25
No Answer	2	3		4
Total	100%	100%		100%
Base	(92)	(92)		(92)

13a. In what forms did the recovered references come to you? (READ LIST)

13b. Which of these do you generally prefer for this type of search?

13c. Which of the others are not preferred but generally adequate?

13d. Are there any that you consider inadequate for this type of search?

Percentages read down ↓ → Percentages read across

	Q. 13a Actual	Q. 13b Preferred	Q. 13c Adequate	Q. 13d Inadequate	No Answer	Total	Base
Complete document	81%	64%	36	—	-	100%	(92)
Abstract	42	68%	22	10	-	100%	(92)
Citation	45	16%	29	54	1	100%	(92)
Document number	2	- %	2	97	1	100%	(92)
Total	170%						
Base	(92)						

14a. Some irrelevant material is usually turned up in a search. What proportion of the total time you spent on this search would you guess was spent in culling out irrelevant or duplicate material?

14b. Was that about right or should you have had to spend less of your time culling out irrelevant or duplicate material? (IF LESS, ASK WHAT PROPORTION)

14c. Of the time you spent on the search, what is the maximum proportion of your time you would have been willing to spend culling out irrelevant material?

	Q. 14a Actual	Q. 14b About right	Q. 14c Maximum
Less than 1/4	44%	44%	16%
1/4 but less than 1/2	7	14	11
1/2 but less than 3/4	29	27	28
3/4 or more	22	14	45
No Answer	1	1	--
Total	100%	100%	100%
Base	(92)	(92)	(92)

15. (HAND RESPONDENT CARD E AND READ ALONG WITH HIM) I am going to show you 7 cards, each of which contains a statement about a performance measure by which document retrieval systems can be judged. It is important to realize that these measures are to a degree in conflict with one another. For example, if you want your requests satisfied as quickly as possible, you normally must expect that some relevant material will be overlooked. Similarly, if you want the system to produce all or nearly all the relevant documents, then you must expect a large number of irrelevant documents in the results. (HAND RESPONDENT GROUP OF CARDS)

Please put these items in the order in which you would least want to compromise on the type of search we've been discussing. Put those you feel strongly you wouldn't want to compromise on your left, those you wouldn't mind compromising on your right, and the others in the middle. Now, put those in each group in order. If you feel two items are equal in importance, put them together.

Order

_____ a. Minimum time to get the major group of relevant references to you.

See _____ b. Minimum of irrelevant material produced by the search

Table _____ c. Minimum of relevant material overlooked by the search

F-2 _____ d. References come to you in form you prefer (complete document, abstract, citation, or document number)

_____ e. Assurance that documents on a given subject do not exist

_____ f. Minimum of effort on your part to communicate your request for a search

_____ g. Certainty that specified sources over certain period of time were searched (certain that 100 percent of the sources were searched, certain that 90% were searched but 10% may not have been searched, etc.)

(AFTER RECORDING, TAKE BACK CARD E AND GROUP OF CARDS.)

16a. On the type of search we've been discussing, how long from the time you make your request can you generally wait for a search which covers 50% of the potential sources?

16b. How long for a search covering 80%?

16c. How long for a search covering all or almost all potential sources?

Q. 16a 50% ____________

Q. 16b 80% ____________ See Table F-3

Q. 16c Almost all ____________

17a. Again on the type of search we've been discussing, how many of your own working days, weeks, or months would you be willing to spend on the search if you could be sure 50% of the relevant sources were located?

17b. How much if 80% of the relevant sources were located?

17c. And if almost all were located?

Q. 17a 50% ____________

Q. 17b 80% ____________

Q. 17c Almost all ____________

See Table F-4

18a. Let's assume for a moment that you initiated a search of the type we've been discussing. Let's say that you personally have spent X amount of time on the search and that the search covered sources up through 2 years ago but nothing more recent. Proportionately how much more working time would you personally be willing to spend to see that sources up through 1 year ago were covered? (OBTAIN ANSWERS IN MULTIPLES OF "X" - "Half again as much time," "Twice as much," etc.)

18b. How much to see that sources up through 6 months ago were located?

18c. And sources up through 1 month ago? See Table F-5

Q. 18a	Up through 1 year ago	________
Q. 18b	Up through 6 months ago	________
Q. 18c	Up through 1 month ago	________

19a. And now a general question about your needs for coverage - that is, the number of sources and period of time covered - for all the kinds of searches you have done in the past few years. How often could you have used these types of searches, ignoring the fact that you may have been unable to do these searches with current tools? (HAND RESPONDENT CARD F)

For the last 5 years of publication:	Often	Once in Awhile	Never	No Answer	Total	Base
The contents of 15 or less journals of special interest to you	82%	16	-	2	100%	(92)
The contents of all the journals covered by the major indexing & abstracting services in your field	29%	68	1	2	100%	(92)
The contents of all the U.S. scientific & technical journals	9%	80	9	2	100%	(92)
The contents of all English speaking scientific and technical journals	14%	69	15	2	100%	(92)
The contents of all the world's scientific & technical journals	8%	73	17	2	100%	(92)

(TAKE BACK CARD F)

19b. Would your answers differ if you weren't limited to searching the last 5 years of publication? (IF YES, ASK HOW ANSWERS WOULD DIFFER)

No difference	84%
Less often	10
More often	3
No answer	3
Total	100%
Base	(92)

And now a few background questions.

20. Name ______________________

21. Company ____________________

22. What is your job title? ____________________

23. Would you classify yourself as a research manager, a senior engineer, an engineer, or a junior engineer?

18%	Research manager
49	Senior engineer
28	Engineer
4	Junior engineer
1	No answer
Total 100%	
Base (92)	

24. In a general technical sense, what do you consider to be your specialty field? For example, computer design, microwave circuit and techniques, etc.

______________________________ See Table F-6

25. What is the highest academic degree you hold and what year was it conferred?

	Degree	Year conferred	
39%	BSEE	'59-'61	28%
38	MSEE	'54-'58	29
8	Engineer	'53 or earlier	43
15	PhD, ScD	No answer	-
-	Other ________	Total	100%
-	No Answer	Base	(92)
Total 100%			
Base (92)			

26. Are you a member of IRE or of AIEE? If so, what type of membership do you hold?

IRE		AIEE	
27%	Not a member	89%	Not a member
–	Fellow	–	Fellow
12	Sr. member	5	Member
58	Member	5	Associate
2	Associate	1	No Answer
1	Student		
Total 100%		Total 100%	
Base (92)		Base (92)	

27. How many years of working engineering experience have you had in these types of organizations? (READ LIST)

Years	
______	University
______	Research Institute
______	Industry
______	Government Labs or Offices
______	Independent Consulting
______	TOTAL

Total Years of Experience

5 years or less	25%
6 - 10 years	35
11 years and over	40
No answer	–
Total	100%
Base	(92)

28. Have you authored any publications or given any technical papers in the last three years? If so, how many technical articles or papers? Any books? Anything else?

51%	None
49	Technical articles or technical papers
–	Books
–	Other ______________
Total 100%	
Base (92)	

No. of Technical Papers

None	51%
1	14
2	12
3-5	14
6 or more	9
No Answer	–
Total	100%
Base	(92)

29. Into which of the following age groups do you fall? (READ LIST)

1%	Under 25
23	25 to 29
30	30 to 34
26	35 to 39
17	40 to 44
3	45 and over
Total 100%	
Base (92)	

Date ____________________

Length of Interview __________ minutes

Table F-1

RESULTS OF THE SURVEY QUESTION REGARDING THE SPECIFICATION OF THE SEARCH

Question 7. Do you recall the exact nature of your request--that is, did you just generally describe the subject, were certain terms used, or what?

Generally described problem, general subject	23%
Several broad headings	13
Fairly specific	15
Specific terms, key words	46
Other	3
No answer	--
Total	100%
Base	(92)

Table F-2

RESULTS OF THE SURVEY QUESTION REGARDING THE

RELATIVE RANKING OF THE REQUIREMENTS

Question 15. Please put these items in the order in which you would least want to compromise. (Note: This is an abbreviated form of the question.)

	Rank	Factors[1/] a	b	c	d	e	f	g
(Most important)	1	36%	4%	20%	10%	5%	9%	11%
	1.5	2	2	-	1	1	2	-
	2	18	6	17	17	19	5	13
	2.5	-	-	1	-	2	-	1
	3	15	8	24	14	12	4	17
	3.5	-	-	1	-	1	-	-
	4	22	10	13	15	12	16	16
	4.5	-	-	-	-	-	-	-
	5	3	15	13	17	18	14	17
	5.5	-	-	-	-	-	-	-
	6	2	33	8	10	12	19	14
	6.5	-	-	1	1	2	-	2
(Least important)	7	2	22	2	15	16	31	9
	No answer	-	-	-	-	-	-	-
	Total	100%	100%	100%	100%	100%	100%	100%
	Base	(92)	(92)	(92)	(92)	(92)	(92)	(92)

1/ The factors were as follows:

a. Minimum time to get the major group of relevant references to you
b. Minimum of irrelevant material produced by the search
c. Minimum of relevant material overlooked by the search
d. References come to you in form you prefer (complete document, abstract, citation, or document number)
e. Assurance that documents on a given subject do not exist
f. Minimum of effort on your part to communicate your request for a search
g. Certainty that specified sources over certain period of time were searched (certain that 100 percent of the sources were searched, certain that 90% were searched but 10% may not have been searched, etc.)

Table F-3

RESULTS OF THE SURVEY QUESTION REGARDING THE
TOLERABLE DELAY IN OBTAINING THE SEARCH PRODUCT

Question 16a. On the type of search we've been discussing, how long from the time you make your request can you generally wait for a search which covers 50% of the potential sources?

Question 16b. How long for a search covering 80%?

Question 16c. How long for a search covering all or almost all potential sources?

	50% of Sources	80% of Sources	Almost all Sources
3 days or less	25%	3%	2%
4 - 7 days	24	19	5
8 - 13 days	4	5	8
2 - 3 weeks	30	33	27
4 - 7 weeks	14	27	24
2 - 3 months	2	11	22
More than 3 months	--	1	9
No answer	--	1	3
Total	100%	100%	100%
Base	(92)	(92)	(92)

Table F-4

RESULTS OF THE SURVEY QUESTION REGARDING THE
TOLERABLE EFFORT TO LOCATE RELEVANT MATERIAL

Question 17a. Again on the type of search we've been discussing, how many of your own working days, weeks, or months would you be willing to spend on the search if you could be sure 50% of the relevant sources were located?

Question 17b. How much if 80% of the relevant sources were located?

Question 17c. And if almost all were located?

	50% of Relevant Sources	80% of Relevant Sources	Almost All Relevant Sources
1 day or less	37%	22%	21%
2 - 4 days	28	36	23
1 week, but less than 2	23	15	21
2 weeks, but less than 3	2	10	14
3 weeks or more	2	10	13
No answer	8	7	8
Total	100%	100%	100%
Base	(92)	(92)	(92)

Table F-5

RESULT OF THE SURVEY QUESTION REGARDING THE TOLERABLE EFFORT TO OBTAIN RECENT MATERIAL

Question 18a. Let's assume for a moment that you initiated a search of the type we've been discussing. Let's say that you personally have spent X amount of time on the search and that the search covered sources up through 2 years ago but nothing more recent. Proportionately how much more working time would you personally be willing to spend to see that sources up through 1 year ago were covered?

Question 18b. How much to see that sources up through 6 months ago were located?

Question 18c. And sources up through 1 month ago?

	Through 1 Year Ago	Through 6 Months Ago	Through 1 Month Ago
1/2 X or less	38%	18%	15%
More than 1/2 X - 1 X	23	30	24
2 X - 4 X	25	29	36
5 or more X	11	20	22
No answer	3	3	3
Total	100%	100%	100%
Base	(92)	(92)	(92)

Note: All data are in terms of effort to update from 2 years ago. Thus the data for 6 months indicate effort to update from 2 years to 6 months ago, and data for 1 month ago indicate effort to update from 2 years to 1 month ago.

Table F-6

SPECIALTY FIELDS OF THE INTERVIEWEES

Question 24. In a general technical sense, what do you consider to be your specialty field? For example, computer design, microwave circuit and techniques, etc.

Circuits and devices (primarily digital techniques)	43%
Microwave and communication engineering	21
Antennas and propagation	10
Communication theory	7
Other	19
No answer	--
Total	100%
Base	(92)

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